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HOT JUPITERS
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Our search for secret living worlds among the barren planets

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Droids that endure the dullest, dirtiest and most dangerous missions in space

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How to find and track your own comet

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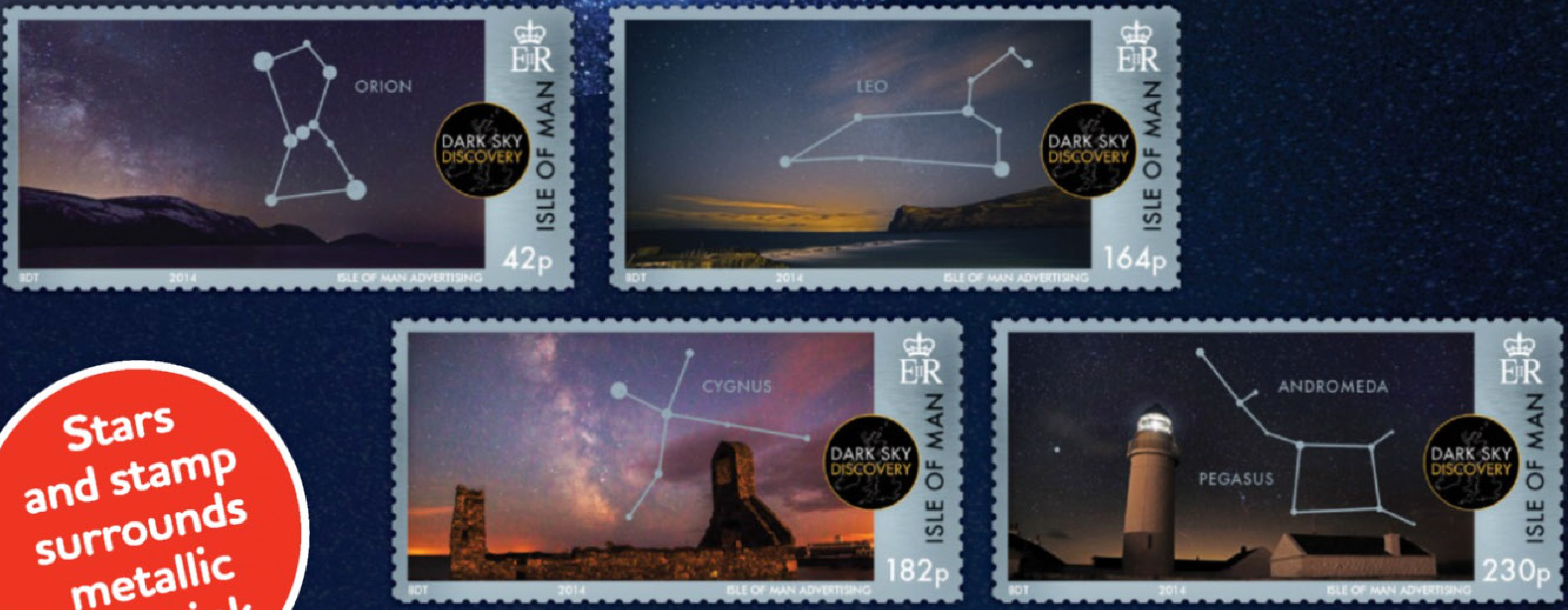

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Discover the wonders of the universe

> "It simply doesn't work like other planets in the Solar System, and we don't know why"
>
> **Dr Chris Arridge, Uranus Pathfinder mission**

A fairly long time ago, during my sixth-form at school, a friend of mine posed a question that still resonates with me now: "If, at the edge of the universe, space stops…" and he'd pause dramatically at this point as if he'd stumbled upon a concept that the world's greatest thinkers hadn't considered, "…then what's behind the stop?"

At the time that was enough to set our young minds into a spin. Years later, we passed it off as some silly bit of naïve philosophical posturing, mostly intended to send anyone who thought about it too much down the rabbit hole, rather than prompt any real discussion. Unfortunately that's about as deep into astronomy as we'd get while passing a fresh bottle of Mad Dog 20/20 around behind the school gym.

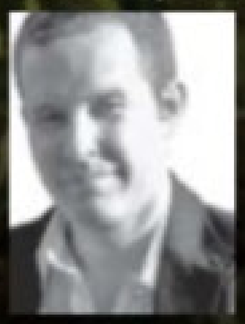
It's a question that's become especially pertinent today though – especially since Hubble's ever-increasing *Deep Field* images, the snapshot of the early universe that is the Cosmic Microwave Background and the promise of being able to peer even further into the past, with future missions like the James Webb Space Telescope.

At a distance of over 13 billion light years from us, many strange phenomena like quasars and galactic superclusters can commonly be observed. Our fumbling attempts to explain them properly aren't helped by the fact that the electromagnetic spectrum, seemingly an everyday absolute here on Earth, is diverted, warped and ultimately breaks down over the vast distances of the cosmos. We can only imagine what's beyond the limits of our observations – but we can have a lot of fun doing it.

Ben Biggs
Editor

Crew roster

Giles Sparrow

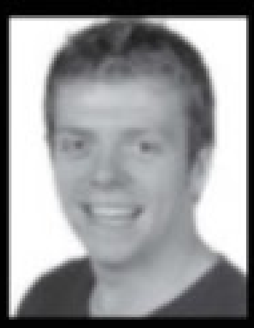


■ What's at the edge of the universe? This month Giles takes us there and even further beyond

Gemma Lavender

■ Gemma's got our cover feature covered again in this issue – she says she could get used to this

Jonny O'Callaghan



■ We're highly impressed with the parade of incredible space robots Jonny dug up this month

Laura Mears

■ Laura deals with one of the biggest topics in space (literally) – a galactic supercluster

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CONTENTS

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LAUNCH PAD

YOUR FIRST CONTACT WITH THE UNIVERSE

06 Eye-catching photos of cool technology and natural cosmic wonders. A stunning journey into space begins here...

FEATURES

16 **Destination ice planet Uranus**
Join Pathfinder on a mission into the freezing depths of this strange giant

26 **Focus On**
Burning gas cloud
See a giant, blistering 7-million-degree cloud of star-forming space

28 **Future Tech**
Remote-control missions
How astronauts will control robots and vehicles on other planets

30 **Edge of the universe**
What strange and wonderful sights are there at the limit of our observations?

40 **All About... the Shapley Supercluster**
A massive cluster of galaxies that's gradually drawing us towards it

48 **What is the Torino scale?**
How do we measure the potential threat of asteroids and comets?

50 **10 incredible space robots**
The machines that work where no astronaut dare tread

58 **Future Tech**
Space fuel depots
How spacecraft will be able to top up their tanks after leaving Earth

60 **Life in the Solar System**
Could life survive in the inhospitable environs of other planets?

69 **5 Amazing facts**
Hot Jupiters
Boiling away in tight orbits, these alien planets were totally unpredicted

70 **Interview**
New Mars orbiter
The MAVEN mission to orbit Mars - and to dodge a comet on the way!

93 **WIN!**
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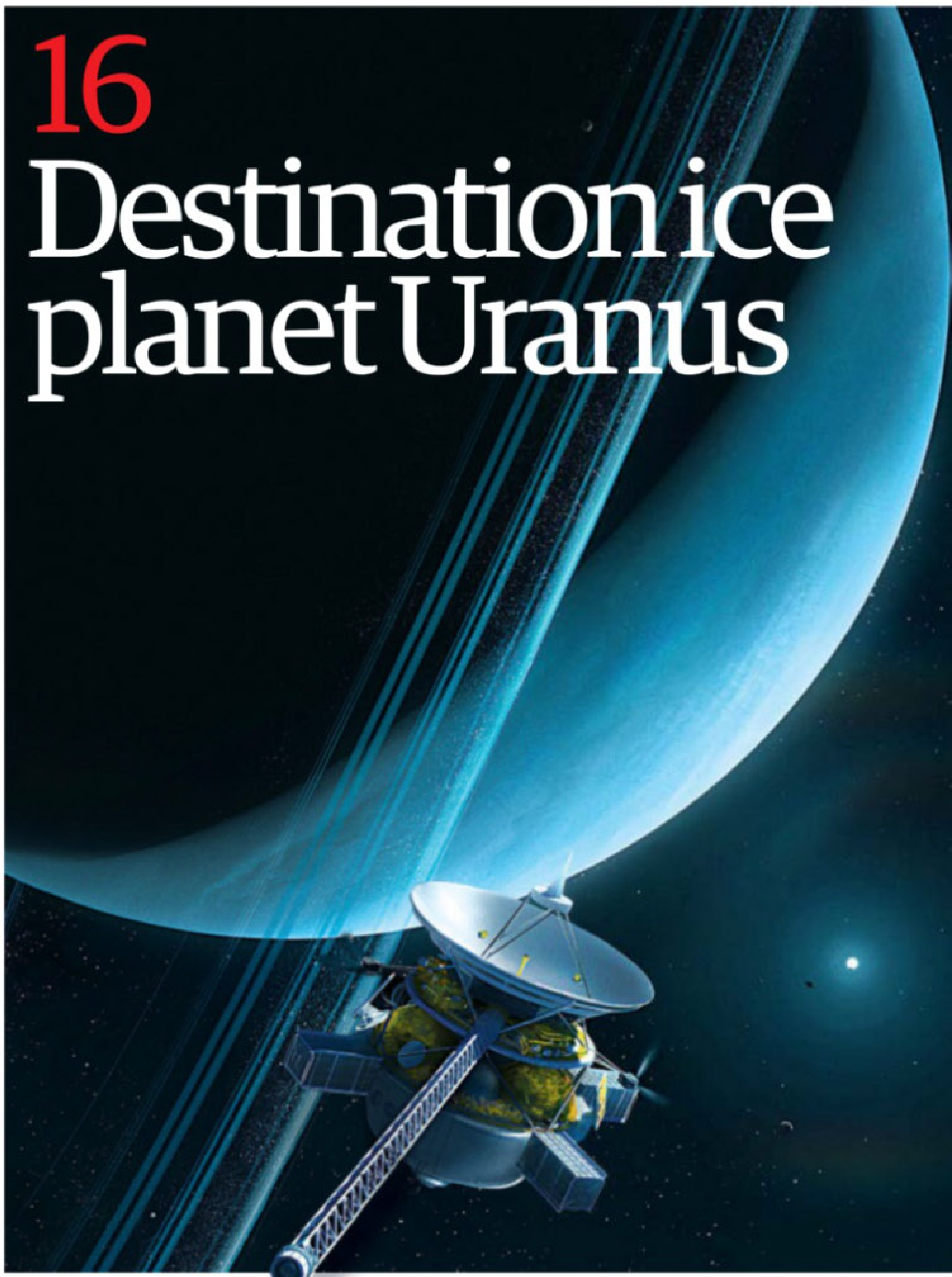

16

Destination ice planet Uranus

40

All About... the Shapley supercluster

> "The emphasis of this mission is on trying to understand the history of Mars's atmosphere"

70 **Bruce Jakosky, principal investigator, MAVEN**

30 EDGE of the UNIVERSE

60 Life in the Solar System

50 10 Incredible space robots

48 What is the Torino scale?

Space ANSWERS

76 Your questions answered

Our experts solve your cosmic questions

STARGAZER

Top tips and astronomy advice for stargazing beginners

82 Comet hunting

How do you go about finding your own comet? Find out here

86 What's in the sky?

The top stargazing sights to see and where you should look this month

88 Me and my telescope

A gallery of beautiful astrophotography and space stories from our readers

94 Astronomy kit reviews

Telescopes, imaging kit, astronomy apps and more in our kit review round-up

98 Heroes of Space

Space celebrity Neil deGrasse Tyson

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Page 74

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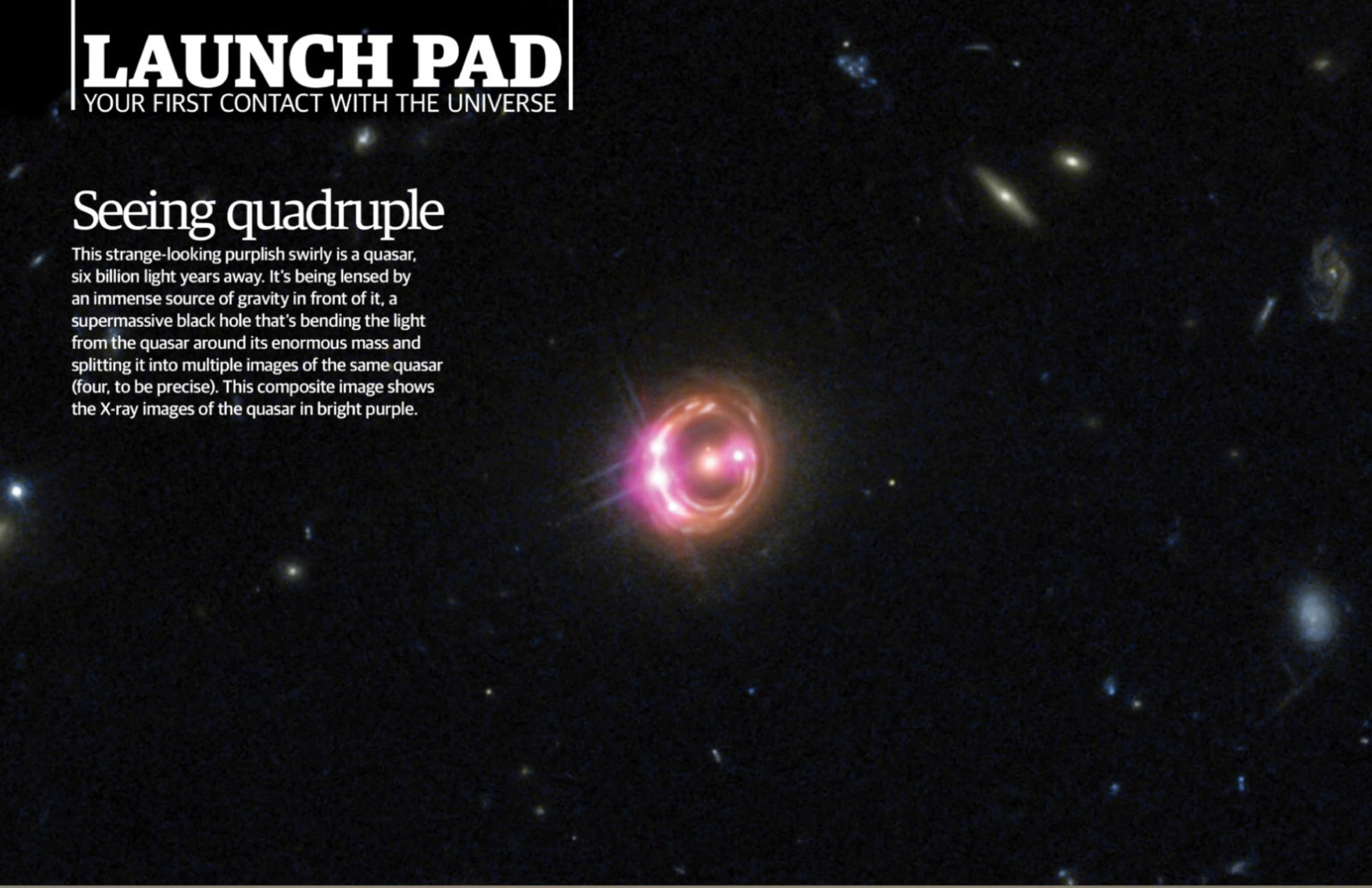
YOUR FIRST CONTACT WITH THE UNIVERSE

Above the storm

This dramatic shot of tropical storm Marie was taken by ESA astronaut Alexander Gerst in August, while aboard the International Space Station for his Blue Dot mission. This six-month mission started in May 2014 and involves various experiments in human physiology (among others) in the space station's lab in order to prepare for further human exploration of the Solar System. Prior to this photo, Marie was a powerful Category-5 hurricane with winds raging at nearly 260 kilometres (160 miles) per hour, threatening the Californian coastline before being downgraded to a tropical storm.

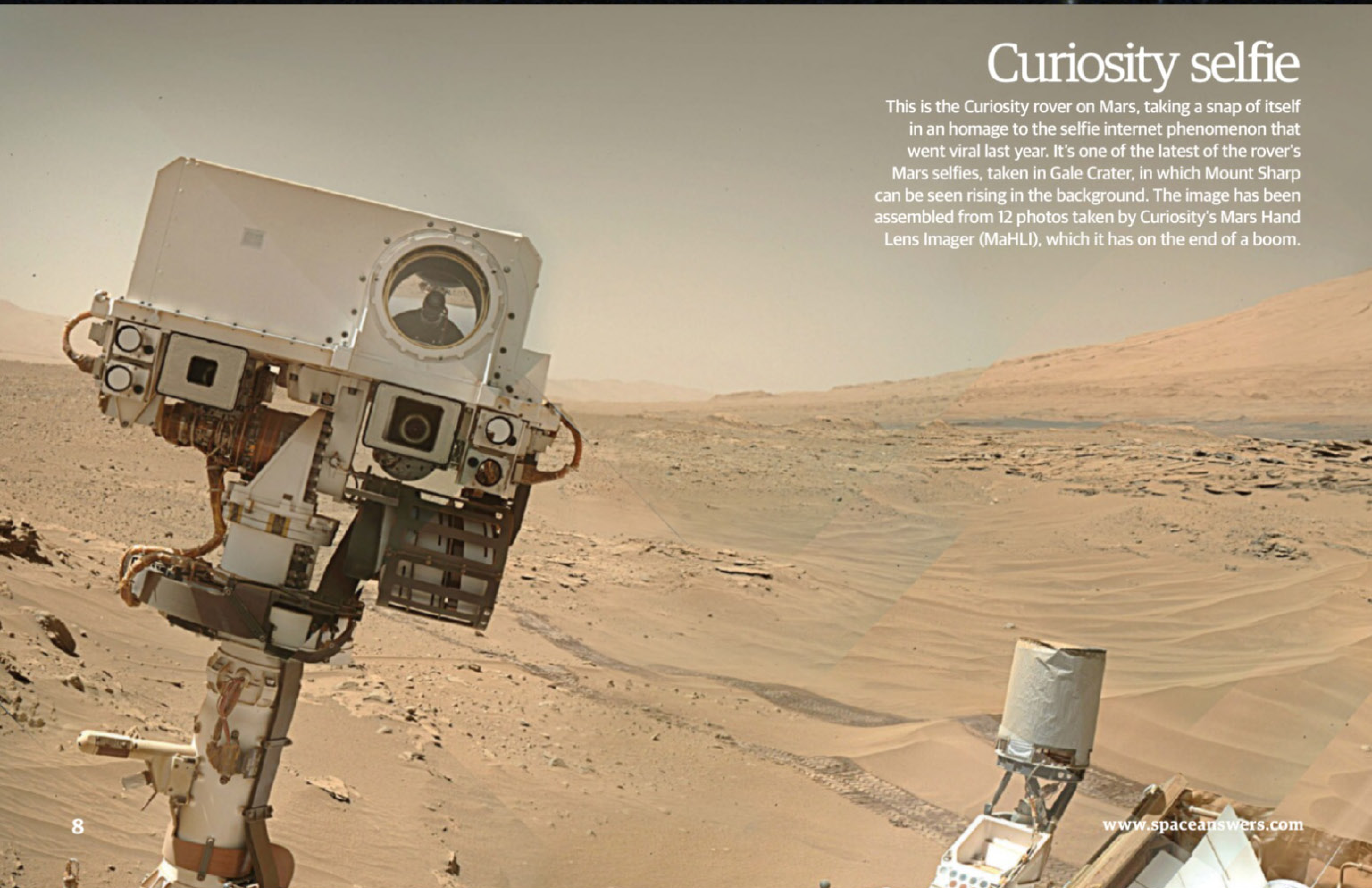
Seeing quadruple

This strange-looking purplish swirly is a quasar, six billion light years away. It's being lensed by an immense source of gravity in front of it, a supermassive black hole that's bending the light from the quasar around its enormous mass and splitting it into multiple images of the same quasar (four, to be precise). This composite image shows the X-ray images of the quasar in bright purple.



Curiosity selfie

This is the Curiosity rover on Mars, taking a snap of itself in an homage to the selfie internet phenomenon that went viral last year. It's one of the latest of the rover's Mars selfies, taken in Gale Crater, in which Mount Sharp can be seen rising in the background. The image has been assembled from 12 photos taken by Curiosity's Mars Hand Lens Imager (MaHLI), which it has on the end of a boom.



Caving astronauts

These are astronauts and they're in a cave – on Earth, we hasten to add, hence the lack of space suits. They're on a simulated mission in Sardinia, Italy, where they must spend two weeks together in an environment that will test their ability to work together, make decisions and solve problems. The situation in the cave is treated as if it were an ISS mission, with methods and a hierarchy that brings it as close to being aboard the space station as possible. This year's cavenauts (as they're known) includes NASA, ESA and Roscosmos astronauts, some of whom have already set foot aboard the ISS, like the ESA's Luca Parmitano, who spent six months aboard the space station in 2013.

Cool technology

These distinctive hexagon shapes are the flight mirrors of the James Webb Space Telescope, which were undergoing cryogenic testing at NASA's Marshall Space Flight Center in Alabama. The X-ray and Cryogenic Facility (XRCF) brings the ambient temperature the mirrors will be exposed to down to as close to the temperature of space as possible, then uses a beam of light that simulates a star to test the JWST's potential infrared light-gathering ability.

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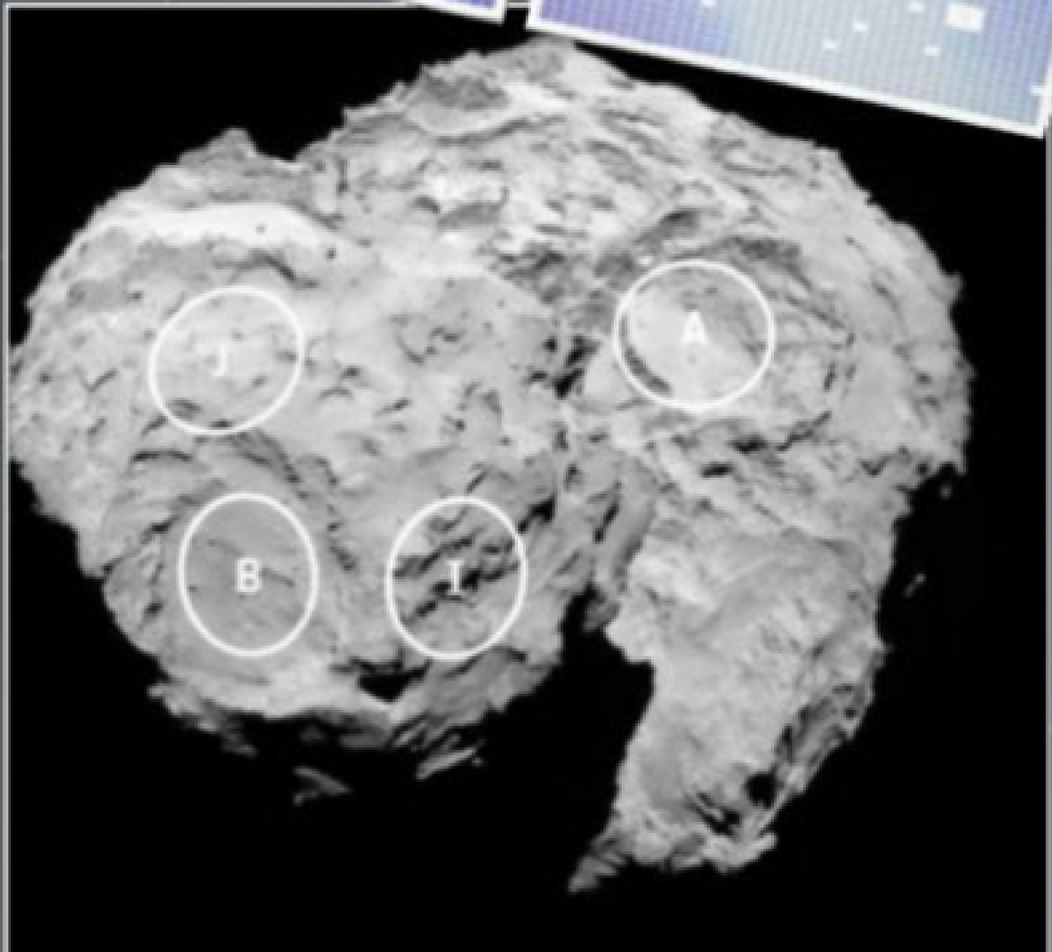
An artist's impression of Rosetta deploying its lander



Four of the five landing sites chosen for the Rosetta mission's Philae lander

Closing in: Possible landing sites chosen for comet-chasing spacecraft

As the Rosetta mission corners its comet, ESA has chosen five possible regions in preparation for landing on its nucleus

After its successful arrival at comet 67P/Churyumov-Gerasimenko in August, ESA's Rosetta spacecraft now has five possible sites in which it can drop its Philae lander. The feat, which is scheduled for mid-November this year, is the first time such a landing has ever been attempted.

"The process of selecting a landing site is extremely complex and dynamic; as we get closer to the comet, we will see more and more details, which will influence the final decision on where we can land," explains Fred Jansen, who is Rosetta's manager and is based at ESA's Space Research and Technology Center in Noordwijk, The Netherlands. "We had to complete our preliminary analysis on candidate sites very quickly after arriving at the comet, and now we have just a few more weeks to determine the primary site. The clock is ticking and we now have to meet the challenge to pick the best possible landing site."

The areas, which have each been assigned a letter from the alphabet, are located on the lobes of 67P/Churyumov-Gerasimenko, with three of the five situated on the smaller of the two. Jansen and his team have to be rigorous when it comes to selecting their ideal location for Philae to land, but for now September will see the scientists putting together possible orbital and operational strategies so that Rosetta can use all of the targeted regions. As the spacecraft prepares to deploy the lander, it will move within 50 kilometres (31 miles) of the comet to study the areas.

"This is the first time landing sites on a comet have been considered," says Philae lander manager, Stephan Ulamec, at the German Aerospace Center. "The candidate sites that we want to follow up for further analysis are thought to be technically feasible on the basis of a preliminary analysis of flight dynamics and other key issues - for example, they all provide at least six hours of daylight per comet rotation and offer some flat terrain. Of course, every site has the potential for unique discoveries."

> "As we get closer to the comet, we will see more and more details, which will influence the final decision on where we can land"
> **Fred Jansen, Rosetta mission manager**

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Telescopes watch the birth of monster galaxy

When galaxies form new stars, they sometimes do so in episodes of activity called starbursts

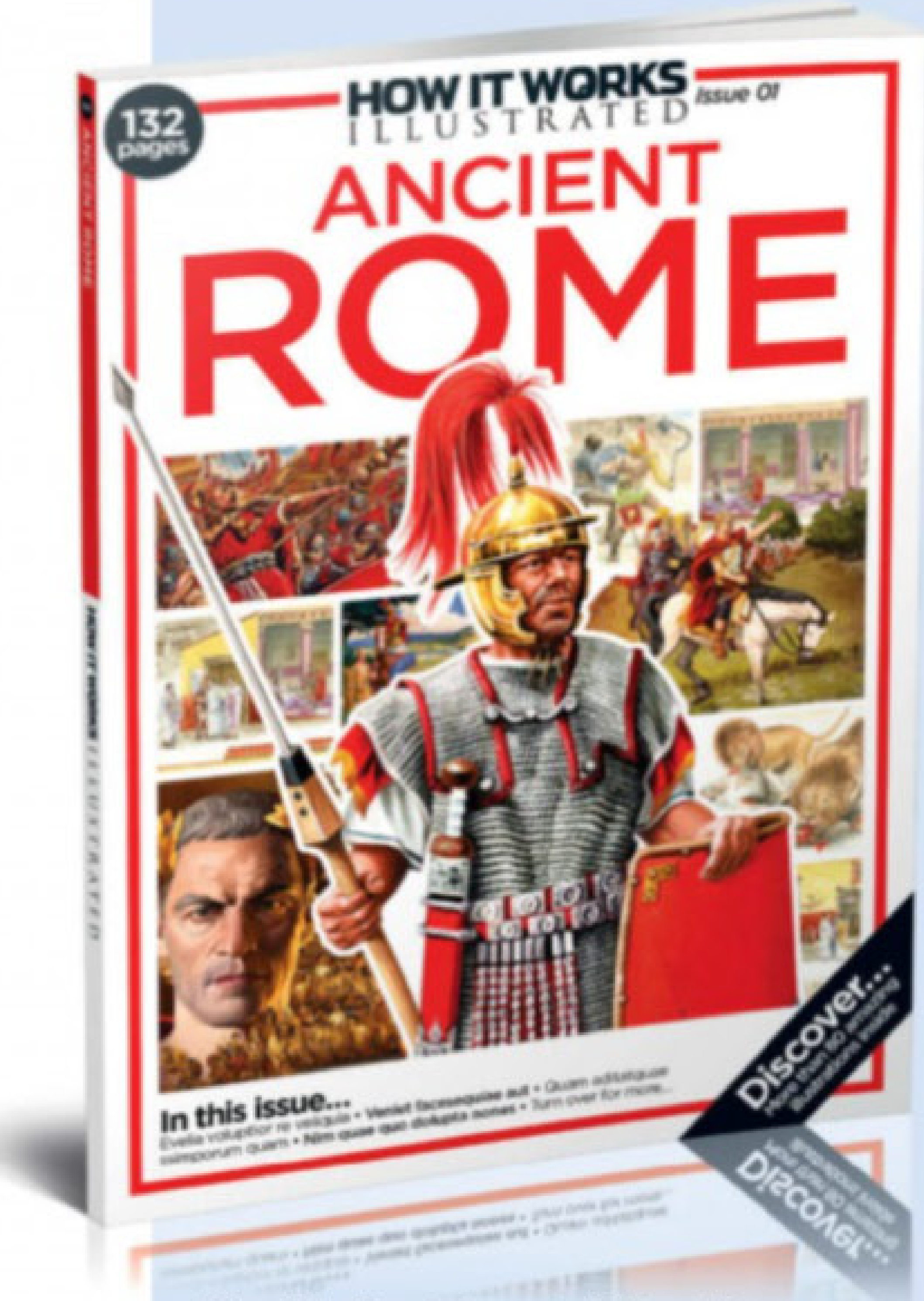
The making of an ancient and massive galaxy has been sighted for the very first time

Astronomers have, for the first time, grabbed a sneak peek into the violent and turbulent birth of the universe's most monstrous galaxies, looking back in time a mere 3 billion years after the Big Bang.

It's been long suggested that these galactic behemoths are breathed into existence by forming from the inside out, making the cores bursting with hot, young stars. "It's a formation process that can't happen anymore," explains Yale University's Erica Nelson who led the study. "The early universe could make these galaxies, but the modern universe can't. It was this hotter, more-turbulent place – these were boiling cauldrons forging stars."

We might not have a time machine to get back to this era in the cosmos' history, but we do have the helping hand of the long-serving Hubble Space Telescope, which tracked down galaxy candidate GOODS-N-774, using its infrared camera. However, it wasn't until Nelson and her team jetted to Hawaii earlier in the year that they saw their galaxy, affectionately dubbed Sparky, being born and creating 300 stars per year. The team had found what they were looking for – and the big tip-off was from Sparky's rapid gushes of gas and the fastest clouds of orbiting gas ever measured.

"Keck Observatory's NIRSPEC [Near-Infrared Spectrograph] provided crucial information," Nelson states. "The really important piece of evidence was the measurement of velocity dispersion. Without that data, it was hard to interpret what was going on." It was this detail that served as the evidence for a giant galaxy in the making. This gas, which features swirling traces of metals fuelling star formation, is something that astronomers have been trying to find for many years. ■



The third instalment of **How It Works Illustrated** takes a trip back in time to Ancient Rome

Discover How It Works Illustrated

From the makers of How It Works: a fun and accessible magazine for young readers

With fun, easy-to-understand explanations and wonderful artwork to amaze the eye, **How It Works Illustrated** is everything kids love about learning in one monthly manual-sized magazine. Each issue is dedicated to explaining all you need to know about one fascinating topic, from ancient Rome to space exploration, and beyond.

Especially designed for younger readers, **How It Works Illustrated** is packed with interesting and engaging stories about the world around us. You'll find all this accompanied by mind-blowing puzzles, challenges and quizzes to stimulate young minds while they learn.

In issue three, we take a trip back to ancient Rome to find out how big the Roman Empire really was, discover how the Romans lived their day-to-day lives, before getting a front-row seat to some of their greatest battles and witnessing the disasters that hit this ancient city. It's an ideal reference for parents and children alike, with hundreds of facts on vital school curriculum topics to nourish enquiring minds.

Discover and explore the world of Ancient Rome, with issue three of **How It Works Illustrated**, the new science magazine for younger readers, on sale from newsagents and supermarkets from 25 September. ■

For full articles: **www.spaceanswers.com**

Starmus festival 2014 launches

Brian May, Stephen Hawking and Richard Dawkins are just some of the names that will be joining forces for this month's astronomy festival. The event will be held in Tenerife, with hundreds of astronomers in attendance.

Exoplanet particles measured

SETI Institute astronomers can now detect particles ten times smaller than the width of a human hair, in exoplanet atmospheres thousands of light years away.

Sun releases same energy as 100,000 years in the past

A neutrino experiment has detected the neutrinos produced by nuclear reactions in the Sun.

The detector has revealed the energy our star releases today is the same as 100,000 years ago.

Send a message to an asteroid!

NASA is now inviting members of the public to send messages and images posted on social media to an asteroid in a time capsule, all loaded aboard their OSIRIS-REx spacecraft.

The mission will be making its way to the Bennu asteroid in 2016.

LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE

New Horizons takes a photo of Neptune on its way to its rendezvous with Pluto in July 2015

Solar System probe passes Neptune

The New Horizons spacecraft has crossed the threshold of its final milestone, on its journey to Pluto, where it should arrive on 14 July 2015. It's taken the probe eight years and eight months to make the 4.4 billion-kilometre (2.75 billion-mile) journey across the Solar System from Earth. That's a world record - a similar journey took Voyager 2 just over 12 years.

The landmark event coincides with the date of Voyager 2's Neptunian crossing too: it was exactly 25 years ago that the probe reached the orbit of Neptune, on 25 August 1989. Back then, of course, the planet was a lot closer than the 4 billion-kilometre (2.5 million-mile) distance it is from New Horizons now.

"The feeling 25 years ago was that this was really cool, because we were going to see Neptune and Triton up-close for the first time," said New Horizons scientist Ralph McNutt, "The same is happening for New Horizons. Even this summer, when we're still a year out and our cameras can only spot Pluto and its largest moon as dots, we know we're in for something incredible ahead."

The New Horizons team isn't sure exactly what they will see when the spacecraft reaches Pluto next year, or whether it will look similar to Neptune's moon, Triton. From Pluto, New Horizons will venture further into the Kuiper Belt, a disc-shaped region of icy objects where even more discoveries await.

Eruption of dust around young star indicates asteroid crash

A team of astronomers have spotted the collision between two large chunks of space rock

The evidence of a colossal smashup between large asteroids has been spotted around a young star, dubbed NGC 2547-ID8, thanks to data taken by NASA's Spitzer Space Telescope. It's collisions like these that can eventually lead to the formations of rocky planets.

"We think two big asteroids crashed into each other, creating a huge cloud of grains the size of very fine sand, which are now smashing themselves into smithereens and slowly leaking away from the star," says the study's leader Huan Meng of the eruption of dust. This marks the very first time scientists have collected data before and after a planetary system smashup, which offers a glimpse into the violent process in which planets like Earth are made.

Rocky worlds are made from debris of swirling dust around a young central star. It's this material that clumps together to form the asteroids that sometimes later run into one another. While asteroids are often destroyed completely when they collide, some survive the smash and mature into fully grown planets.

"We are watching rocky planet formation happen right in front of us," says George Rieke, co-author of the study, who also led one of the instrument-developing teams on the Spitzer telescope project. "This is a unique chance to study this process in near-real-time."

Astronomers hunt for universe's first light

Galaxies or quasars may give the cosmos the UV light detected today

What lit up the universe? That's one question that researchers at University College London (UCL) are trying to answer. According to their progress so far, we could soon know more about the origin of the ultraviolet light that bathes the universe, in the hopes of learning how galaxies are born.

"Which produces more light? A country's biggest cities or its many tiny towns?" poses cosmologist Andrew Pontzen, who has teamed up with fellow UCL cosmologist Hiranya Peiris as well as scientists at Princeton and Barcelona Universities. "Cities are brighter, but towns are far more numerous. Understanding the balance would tell you something about the organisation of the country. We're posing a similar question about the universe: does ultraviolet light come from numerous but faint galaxies, or from a smaller number of quasars?"

Finding out if gaggles of galaxies are capable of outshining the brightest objects in the cosmos - known as quasars - will help astronomers to piece together a picture of how the universe built up its population of today's stars and planets. The quasars themselves are so bright that they act as distance markers, illuminating up to 95 per cent of the way across the observable universe with their ancient light. What's more, Pontzen and his team think this light, which hits the hydrogen gas thought to permeate the universe, could tell us something about the main sources of illumination in the universe.

With plain, neutral forms as well as charged forms of hydrogen gas in existence, astronomers are thinking that an even spread of the former would suggest a great proportion of light comes from galaxies. A patchwork of charged and neutral hydrogen gas would indicate quasars caused the origin of light.

What lit up the universe - galaxies or quasars?

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Destination ice planet
URANUS

It might look like a plain turquoise ball, but planet number seven is a world that scientists are targeting with a new mission to explore its mysterious depths

Written by Gemma Lavender

"Uranus simply doesn't work like other planets in the Solar System, and we don't know why," declares Dr Chris Arridge, a physicist studying the giant outer planets of the solar neighbourhood.

To Arridge and the other scientists puzzled by the planet, this ice giant poses a lot of questions that need answering: why it has a tilted appearance, what's within its mysterious interior, what are the workings of its atmosphere and many more.

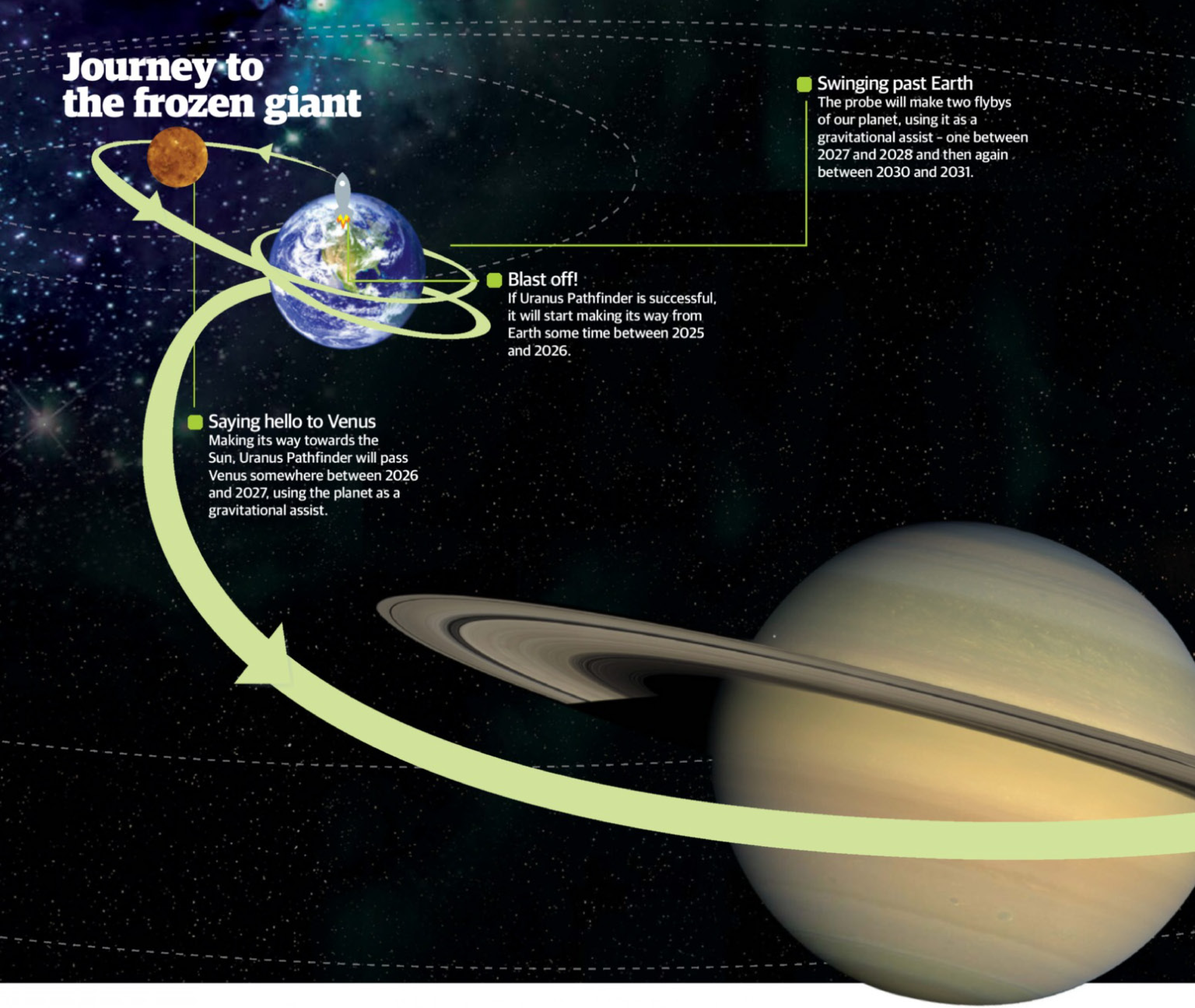
Arridge, a scientist at the Mullard Space Science Laboratory, is intent on finding the clues to answering these questions. He wants to send a messenger to Uranus, a probe that will carry the toolkit to solve some of the mysteries that surround the seventh planet from the Sun. "We've only looked at Uranus close-up using a single spacecraft, and that was a flyby by Voyager 2 in 1986. We have to send another mission," he says.

Waiting in the wings and ready to step up to the challenge is Uranus Pathfinder, an orbiter dreamt up by Arridge himself, which would make its way to the ice giant to seek the much-awaited answers about the nature of Uranus. You might have heard of this mission before, because it's been brought to the attention of the European Space Agency (ESA) as a possible candidate to be developed to leave the Earth's atmosphere. Sadly the mission didn't make the final cut when the agency called out for suggestions for medium-class missions. ESA was concerned that, so far from the Sun, the spacecraft would have problems generating power.

"One of the big problems with a mission to Uranus is how you produce the electricity to power the spacecraft," explains Arridge. Unfortunately his mission lost out to PLATO, which is part of ESA's Cosmic Vision programme to study any Earth-like planets. "A lot of missions, like ESA's Rosetta mission, convert the power of sunlight into electricity. Sunlight is very, very weak near Uranus, almost 400 times weaker than near Earth, so you can't use solar power – you'd need solar arrays at least the size of an IMAX cinema screen!"

Such a mission would therefore have to mimic NASA's Cassini-Huygens mission to Saturn and the New Horizons spacecraft destined to reach Pluto, in that Uranus Pathfinder would need a nuclear power source. "This works by carefully taking a designed piece of radioactive material and converting the heat from radioactive decay into electricity," says Arridge. "The careful design comes in so we can make sure

Journey to the frozen giant



Swinging past Earth
The probe will make two flybys of our planet, using it as a gravitational assist – one between 2027 and 2028 and then again between 2030 and 2031.

Blast off!
If Uranus Pathfinder is successful, it will start making its way from Earth some time between 2025 and 2026.

Saying hello to Venus
Making its way towards the Sun, Uranus Pathfinder will pass Venus somewhere between 2026 and 2027, using the planet as a gravitational assist.

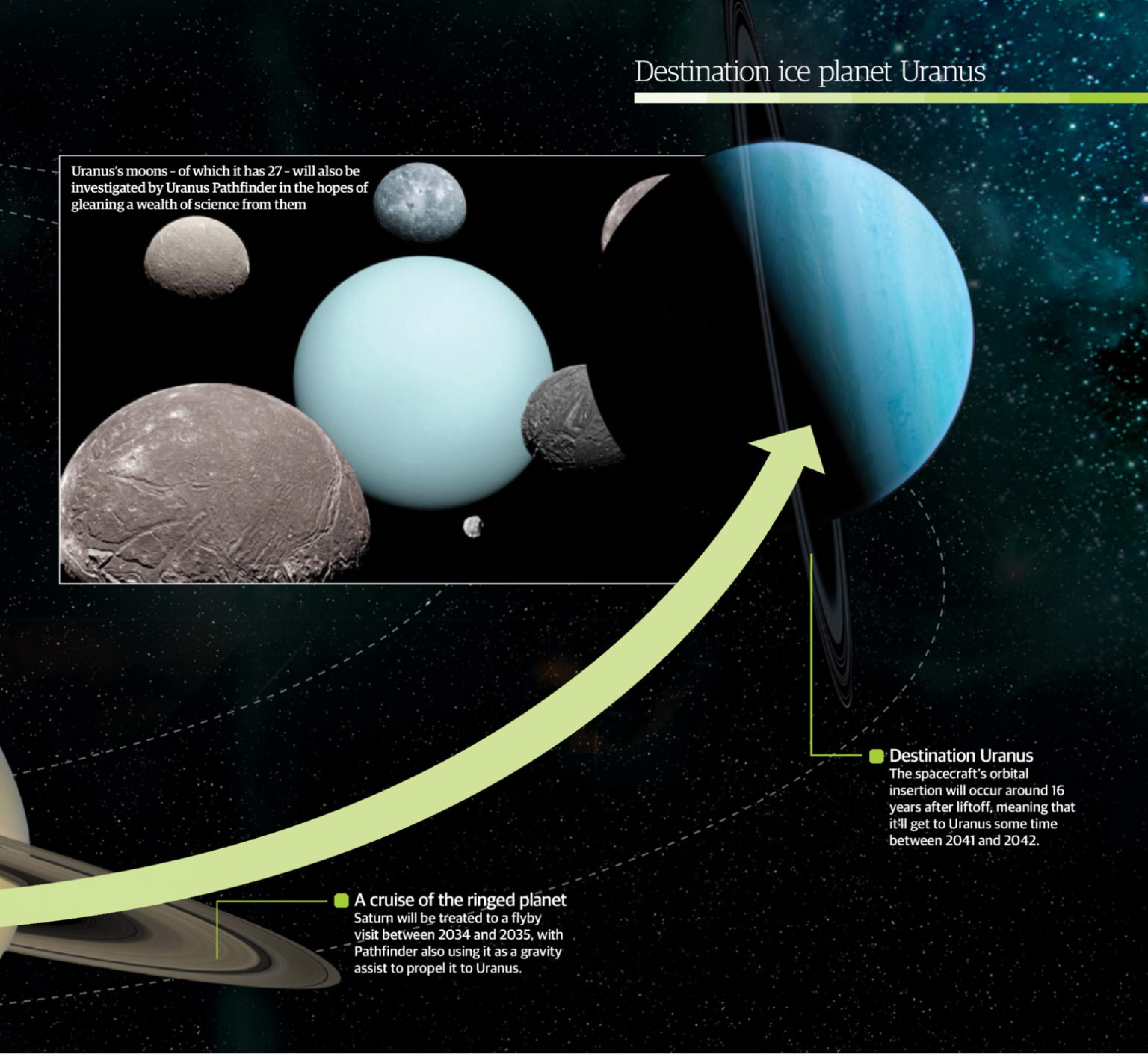
> "There are a great many things we don't understand about Uranus as a planet"
>
> **Dr Chris Arridge**

if there were an accident and the spacecraft either burnt up in the atmosphere, or the rocket exploded after launch, then the radioactive material wouldn't be released into the environment."

As the proposed mission's lead scientist, Arridge is aware that the technology he speaks of isn't as highly advanced in Europe as he'd like. He firmly states that if we ever want to push beyond the orbit of Jupiter, then working on this technology is critical. "Although a lot of people, particularly in the United Kingdom, are working hard on this," he adds.

Despite the mission's previous rejection, Arridge and his team of 120 scientists are not about to give up. They are backing Uranus Pathfinder all the way and will be resubmitting their concept, because they believe it's essential to understanding the planet, whose behaviour and characteristics continue to elude us. "Any day now, ESA is going to issue a call asking for ideas for its fourth medium-class mission (known as M4), which follows Solar Orbiter (M1), EUCLID (M2 – a dark energy survey mission) and PLATO (M3)," he explains enthusiastically. "We will be revisiting Uranus Pathfinder so we can submit it to this M4 call. If accepted, ESA is expected to require a launch in 2025 or 2026."

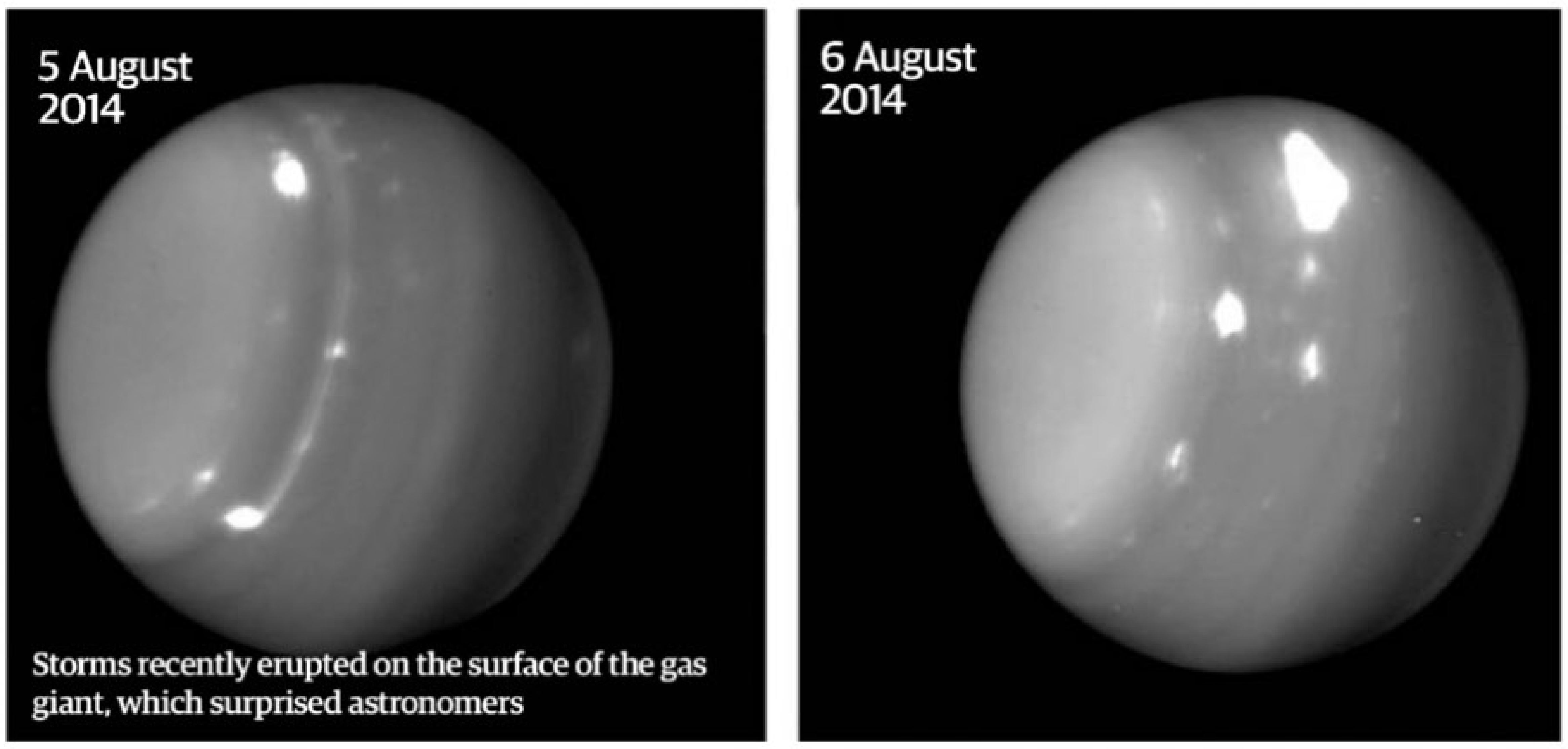
It's set to be a monumental mission of great scientific worth and importance. Destined to perform the first detailed study of an ice giant system, the Uranus Pathfinder probe will slip into orbit around the planet before turning its attention towards imaging, analysing the mysterious world and its major orbiting moons. "There are a great many things we don't understand about Uranus as a planet," Arridge elaborates. "I think every scientist would give you a different set of big mysteries."



Uranus's moons – of which it has 27 – will also be investigated by Uranus Pathfinder in the hopes of gleaning a wealth of science from them

Destination Uranus
The spacecraft's orbital insertion will occur around 16 years after liftoff, meaning that it'll get to Uranus some time between 2041 and 2042.

A cruise of the ringed planet
Saturn will be treated to a flyby visit between 2034 and 2035, with Pathfinder also using it as a gravity assist to propel it to Uranus.



5 August 2014

6 August 2014

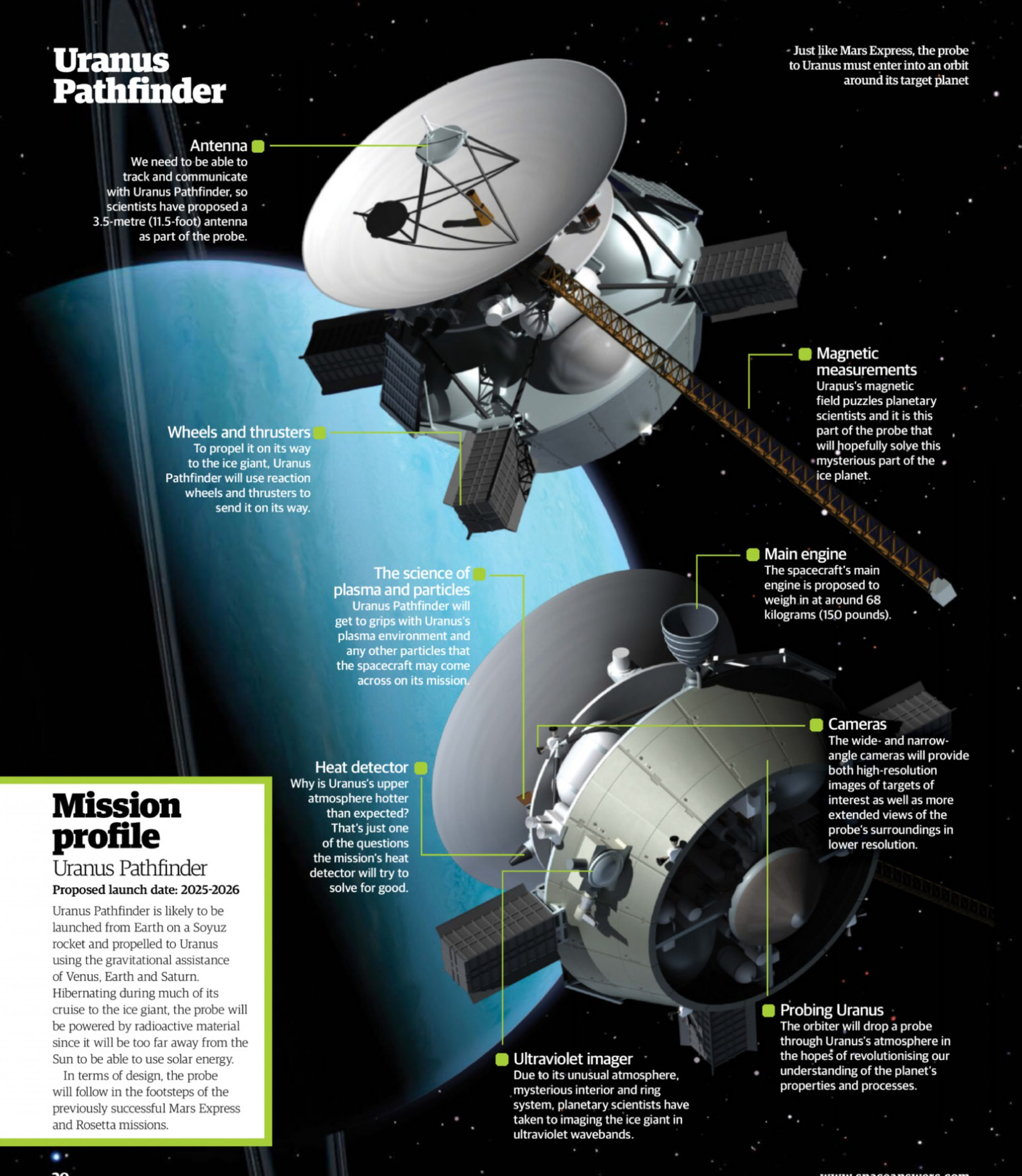
Storms recently erupted on the surface of the gas giant, which surprised astronomers

Rolling around the Sun on its side, beyond the orbit of Saturn, we only have an inkling of the planet's structure. We think that it's made mainly of a cocktail of volatile ices, which include water, ammonia and methane. That's why Uranus and Neptune are known as the ice giants, but just how much ice Uranus has involves quite a bit of guesswork. With the planet's mysteries have come many scientific models that have aimed to lock down some answers, but they have left planetary scientists with nothing but frustration and a skew of results.

As it stands, there's no precise figure for Uranus's ice mass and we're not fully certain on how much hydrogen and helium gas can be found there. The planet's core is even more puzzling. Supposedly comprised of molten metals such as iron and nickel,

Uranus Pathfinder

Just like Mars Express, the probe to Uranus must enter into an orbit around its target planet



Antenna
We need to be able to track and communicate with Uranus Pathfinder, so scientists have proposed a 3.5-metre (11.5-foot) antenna as part of the probe.

Magnetic measurements
Uranus's magnetic field puzzles planetary scientists and it is this part of the probe that will hopefully solve this mysterious part of the ice planet.

Wheels and thrusters
To propel it on its way to the ice giant, Uranus Pathfinder will use reaction wheels and thrusters to send it on its way.

The science of plasma and particles
Uranus Pathfinder will get to grips with Uranus's plasma environment and any other particles that the spacecraft may come across on its mission.

Main engine
The spacecraft's main engine is proposed to weigh in at around 68 kilograms (150 pounds).

Cameras
The wide- and narrow-angle cameras will provide both high-resolution images of targets of interest as well as more extended views of the probe's surroundings in lower resolution.

Heat detector
Why is Uranus's upper atmosphere hotter than expected? That's just one of the questions the mission's heat detector will try to solve for good.

Probing Uranus
The orbiter will drop a probe through Uranus's atmosphere in the hopes of revolutionising our understanding of the planet's properties and processes.

Ultraviolet imager
Due to its unusual atmosphere, mysterious interior and ring system, planetary scientists have taken to imaging the ice giant in ultraviolet wavebands.

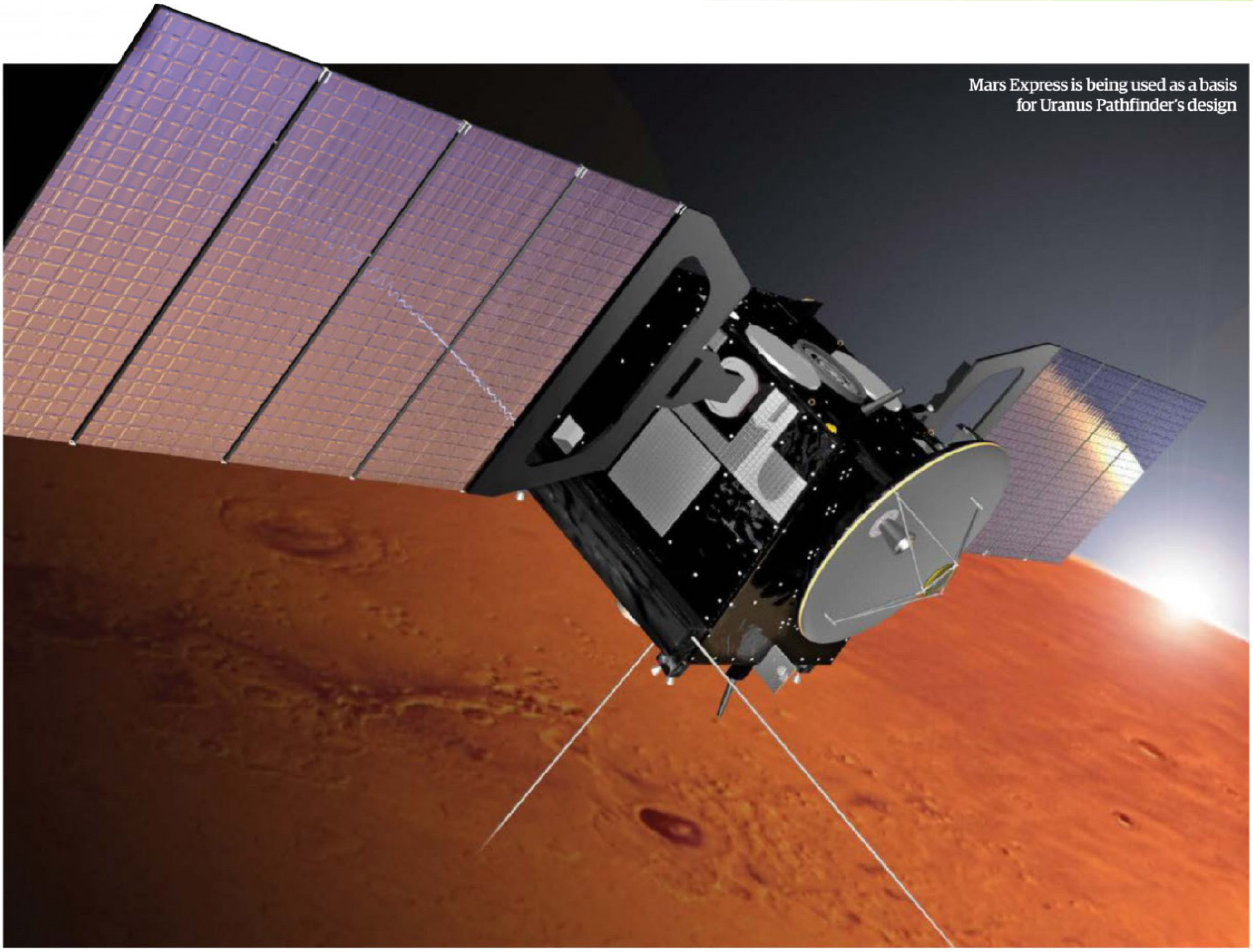
Mission profile

Uranus Pathfinder

Proposed launch date: 2025-2026

Uranus Pathfinder is likely to be launched from Earth on a Soyuz rocket and propelled to Uranus using the gravitational assistance of Venus, Earth and Saturn. Hibernating during much of its cruise to the ice giant, the probe will be powered by radioactive material since it will be too far away from the Sun to be able to use solar energy.

In terms of design, the probe will follow in the footsteps of the previously successful Mars Express and Rosetta missions.



Mars Express is being used as a basis for Uranus Pathfinder's design

scientists have only really been able to infer that it weighs just over half the mass of Earth, surrounded by a 13.5 Earth-mass mantle of ices topped off by an atmosphere that also weighs half the Earth's mass. The core is crushed together under a pressure 8 million times greater than Earth's surface pressure and a top temperature of 5,000 degrees Celsius (9,032 degrees Fahrenheit).

Given this tremendous heat, you might be wondering how it is the so-called ices that comprise the planet's bulk fit in. "We call gases like ammonia and methane ices," Arridge explains, stressing that Uranus isn't made of the frozen ice that's common to us here on Earth. Instead, hot and dense fluids rage through its mantle in a doubtless chaotic display. This carries with it the ability to transport electricity to the highest degree.

Over the years we've painted a picture of Uranus and with it scientists have imagined all sorts happening on the ice giant's surface – from diamonds raining down from its skies, all the way through to large lumps of diamond, dubbed diamond-bergs, floating through an ocean of liquid diamond at the mantle's base. However, until we've sent a Uranus mission to the outer Solar System, there's no way of truly knowing what's real and what's the product of an overactive scientific imagination.

"This planet is the odd one out, toppled over at an angle of 97 degrees onto its side and rolling, instead of spinning"

"One of the things we really want to do is to understand the interior of Uranus. To do that we really need to get close to it," explains Arridge. "With a flyby you only get that over a narrow range of latitudes and longitudes [because you fly past the planet so quickly], but the coverage is needed over as much of the planet as possible. With an orbiter we will get close to Uranus many times."

It's said that the constituents that supposedly make up Uranus could be mixed together in such a way that we're unable to fit it to the so-called three-layer model. This is essentially where a planet features a core, mantle and atmosphere similar to the other planets of our Solar System. Additionally, the goings-on beneath its bland-looking exterior could be explained by another unusual factor that it possesses – its extremely weird spin.

Take one look at Uranus and you'll see that this planet is the odd one out, toppled over at an angle of 97 degrees onto its side and rolling, instead of spinning, around the Sun like its neighbouring worlds. It's thought that some time ago, the ice giant was accosted by an object or two that knocked it over. However, this is still just a theory that has yet to be proven. "Was it a collision that tilted Uranus onto its side?" Arridge wonders. "If so, what other effects did it have?"

Although Uranus's mysteries lie deep beneath the visible turquoise upper atmosphere, Uranus Pathfinder would be able to see through the atmospheric haze to what lies beneath. "We'll have much greater capabilities since we'll be using an instrument to take pictures in near-infrared light," explains Arridge. "We can learn so much about what makes up the surface of a moon, or the rings, or the atmosphere, by studying it in this wavelength." If the probe finds anything out, then we might be lucky in locking down specifics about the orientation of its magnetic field and the locations of its magnetic poles. We suspect that if Earth were tilted to the same extent as Uranus, our home planet's magnetic axis would dramatically change and spear through

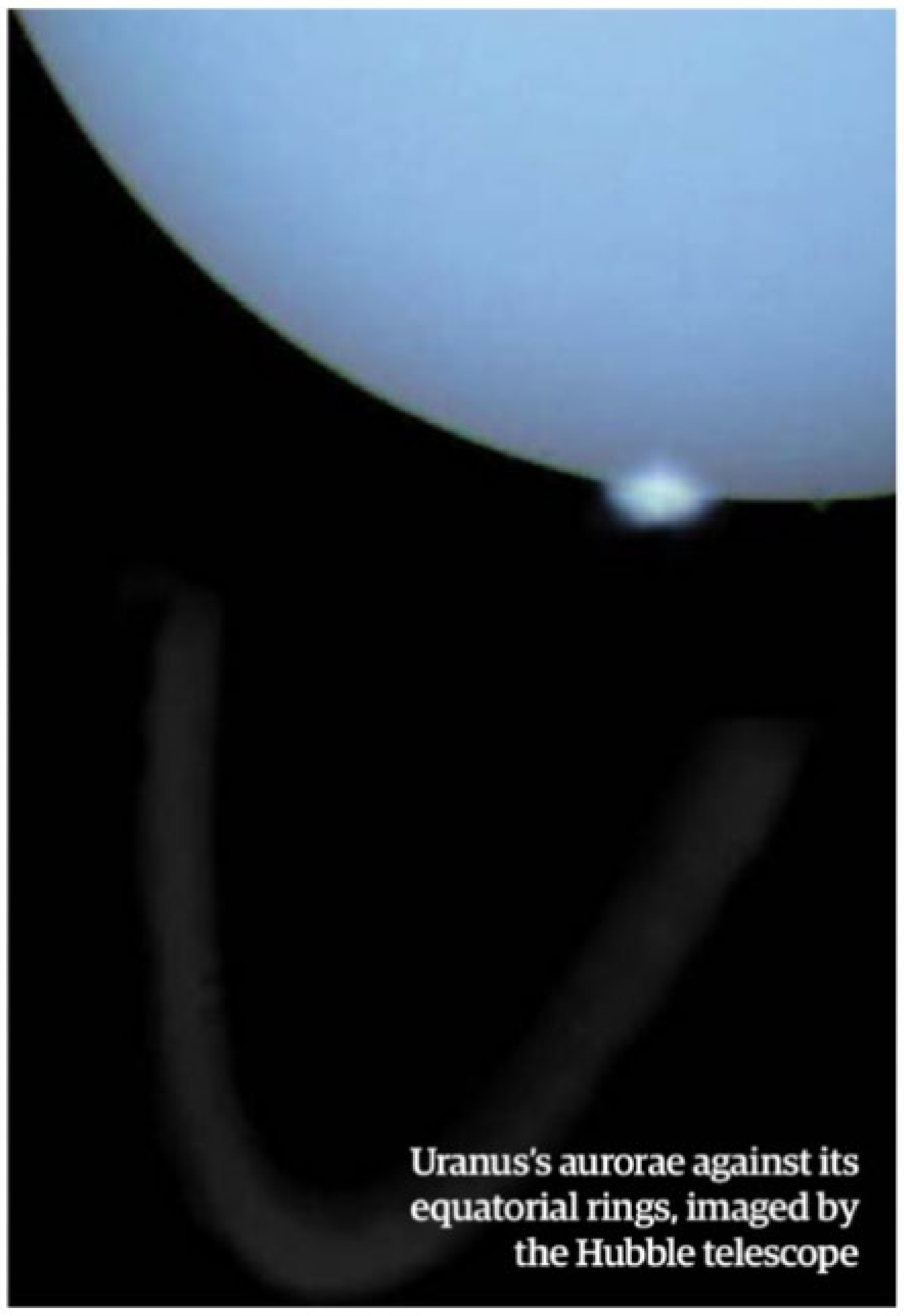
New Orleans, rather than through the current poles at the Arctic and Antarctic.

"The conditions at Uranus are really strange," echoes Tom Stallard, a planetary scientist at the University of Leicester, who is also involved in the Uranus Pathfinder mission. He's interested in the ice giant's upper atmosphere and the aurora that occurs there. "For most planets in the Solar System, the interaction with the Sun's solar wind has a strong affect on both the aurora and the upper atmosphere. This configuration, where the magnetic poles of the planet rotate around, [seeming almost like a] lighthouse that has fallen over, must result in a very unusual, if not highly complicated, magnetic field interaction with the solar wind, in turn producing very strange aurora."

Before Uranus Pathfinder becomes too focused on one thing, we must remember that Uranus has other fascinating features to explore. In 1977 its rings were discovered, when the planet was observed to block the light of a distant star - an occultation - from Earth. It had been expected that the star would just wink out of visibility once but in actual fact, it did so multiple times, as each ring also blocked its light as seen from Earth.

These rings are very different to Saturn's and 13 have now been identified in total, all made from dark, dusty particles. Because Uranus is tilted over, so are its rings. Whether they formed like Saturn's rings, or how long they have existed around Uranus is unknown, but Pathfinder will be tasked with finding this out, just like NASA's Cassini mission has been seeking to do the same for Saturn's rings.

"Because the rings cover a large area, but are quite delicate, they can be useful as detectors for an array of processes," says Matthew Tiscareno of Cornell University, who is one of Arridge's 120-strong team. For example, studying the rings could tell us about the amount of dust and micrometeoroids zipping


Uranus's aurorae against its equatorial rings, imaged by the Hubble telescope

Uranus: the missing pieces

From the interior, to its rings and out to its moons, Uranus is a planetary oddball waiting to be figured out

01 What is the mystery behind Uranus's magnetic field?

Chris Arridge, Uranus Pathfinder's lead scientist on Uranus's magnetic field

"Uranus's [tilted] configuration, where the magnetic poles of the planet rotate around something akin to a lighthouse that has fallen over, must result in a very unusual, if not highly complicated magnetic field interaction with the solar wind. This in turn would produce very strange aurora."

02 What don't we know about the planet's interior?

Nadine Nettelmann, Uranus Pathfinder's lead scientist for the interior of Uranus

"Our key questions about [Uranus's] internal state are pretty fundamental in nature. What is the internal composition, in particular does Uranus consist primarily of ices as suggested from its observed density? Is the interior convective or in part stably stratified as indicated by its observed low luminosity."

03 What can the rings tell us?

Matthew Tiscareno, Uranus Pathfinder's lead scientist for Uranus's rings

"Uranus's rings are an important means for learning about Uranus and its environment. The rings cover a large area but are also quite delicate, so are useful as detectors for an array of processes. The interior structure of Uranus governs some aspects of certain periodic movements of narrow rings, so observing the latter helps us to characterise the former. There could be waves that propagate through rings of Uranus, driven by structures inside it. Observable effects within the rings can also tell us about hard-to-observe processes in Uranus's magnetosphere and in the micrometeoroids that constantly bombard the planet's system."

04 What's so weird about Uranus's atmosphere?

Leigh Fletcher, Uranus Pathfinder's lead scientists on Uranus's atmosphere

"We don't really have a good understanding of how the atmosphere responds to vast changes in sunlight. Uranus appears more sluggish than any other world, with very few discrete cloud features popping up until relatively recently… For a world with an extreme axial tilt, we'd like to find out why this planet seems less active than Neptune's rapidly varying atmosphere. We also still don't understand why Uranus is slowly cooling."

05 Why do we need to know more about how Uranus was made?

Olivier Mousis, Uranus Pathfinder's lead scientist on the formation of Uranus

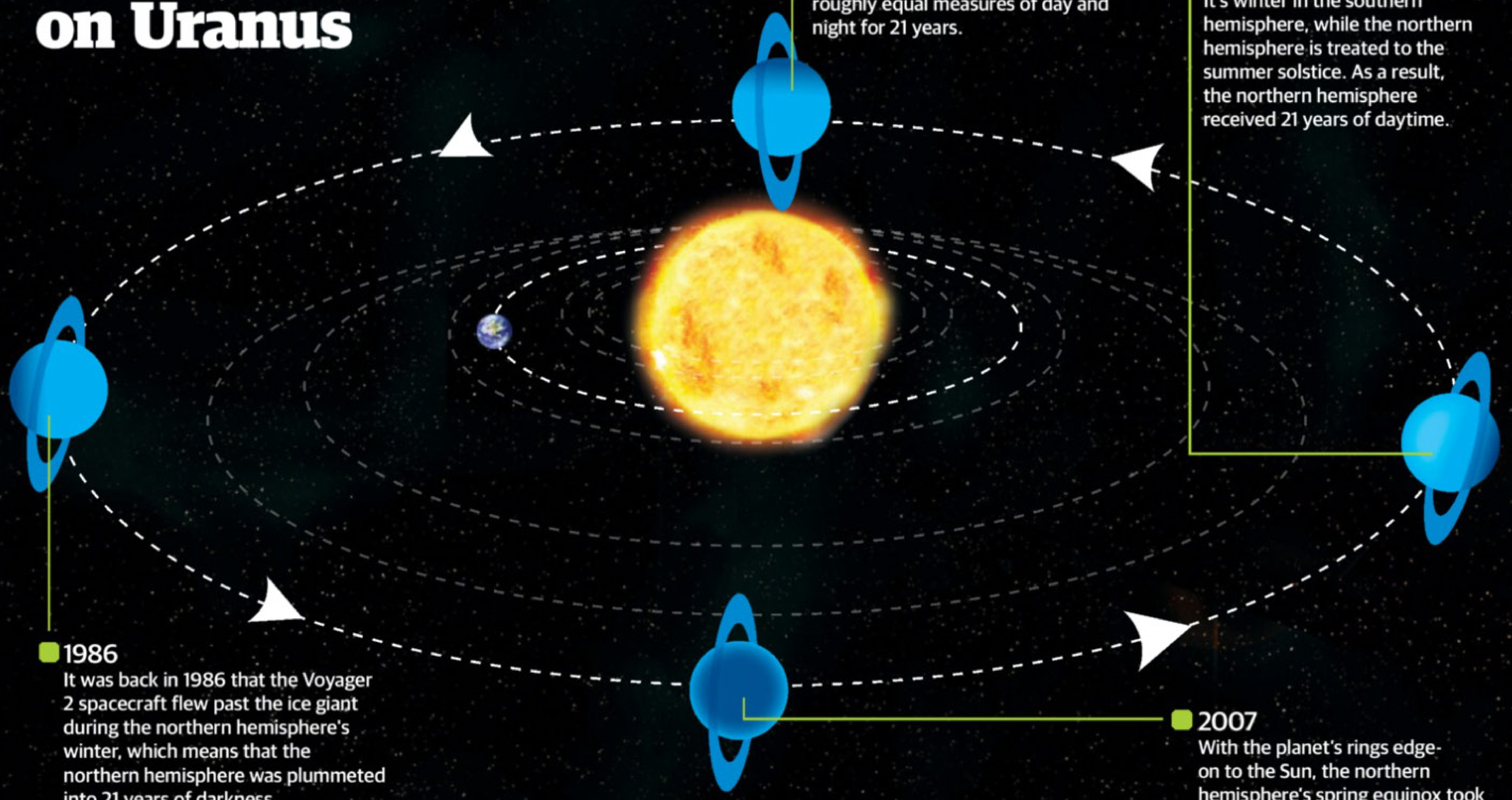
"The only element whose abundance has been roughly measured – in the envelope of this planet – is carbon. The abundances of the other species, in particular oxygen, nitrogen and sulphur have not been measured. This implies that we don't know precisely the formation conditions of Uranus. We believe that the reason why Uranus is so different to Jupiter and Saturn is because [it] didn't take the time to end its formation before the protosolar nebula dissipated."

06 Why are Uranus's moons also odd?

Gabriel Tobie, Uranus Pathfinder's lead scientist on Uranus's moons

"The orbital plane of the regular satellites is tilted by the same angle as Uranus, compared with the Solar System's plane. [This is likely because] the ice giant might have been impacted by a wandering planet whose mass would be close to that of Earth. The impact angle would have been oblique and forced the proto-Uranus to tilt. The satellites would have formed from the disc created from the collision."

Seasons on Uranus



1965
In this year the northern hemisphere of the planet underwent its autumn equinox while the southern half was in spring. During this time, there were roughly equal measures of day and night for 21 years.

2028
It's winter in the southern hemisphere, while the northern hemisphere is treated to the summer solstice. As a result, the northern hemisphere received 21 years of daytime.

1986
It was back in 1986 that the Voyager 2 spacecraft flew past the ice giant during the northern hemisphere's winter, which means that the northern hemisphere was plummeted into 21 years of darkness.

2007
With the planet's rings edge-on to the Sun, the northern hemisphere's spring equinox took place around seven years ago. It is this time of year where there are 21 years of normal days and nights.

back and forth near Uranus, which may be colliding with the rings. They could possibly be eroding them and turning them dark over many millions, or even billions of years. Gravitational fields that cause ripples in the rings could also illuminate the interior structure of the planet. Meanwhile, during the window of time between Voyager's 1986 flyby and whenever Uranus Pathfinder sets off for the seventh planet, the Hubble Space Telescope has been attempting to fill in the gaps. It has made several new discoveries, including new moons that shepherd the most-recently discovered outer ring.

Like the moons of Jupiter and Saturn, the natural satellites of Uranus are just as spectacular as their parent planet. Chief among them is Titania, which is Uranus's biggest moon, at an impressive 1,578 kilometres (980 miles) in diameter. Compared with the giants that are Earth's, Jupiter's and Saturn's biggest moons, this satellite isn't really that big.

Some scientists suspect that Titania could have a hidden ocean beneath its icy, cratered surface, kept liquid through a mixture of heat generated by gravitational tides from nearby Uranus, radioactive decay and the presence of an antifreeze such as ammonia. So, while there is no chance for life on Uranus, there is a chance that life could exist in the hypothetical ocean of Titania.

Uranus's four other major moons are Miranda, Oberon, Ariel and Umbriel, all named after characters from the writings of both William Shakespeare and Alexander Pope. The smallest of these five main satellites is Miranda, which is about 470 kilometres (292 miles) across. Scientists have likened the surface of Miranda, which Voyager saw up-close, to a patchwork quilt with areas made from various textures. This appears to be a moon that has been smashed apart and then badly reassembled, so not all the pieces really fit. Parts of its surface look melted, while others are covered in mountains and valleys.

Similarities have been drawn between Miranda and Saturn's moon Enceladus, which has giant geysers of water vapour blasting out from huge cracks in the surface. Scientists are convinced that Enceladus has an underground ocean, like Titania, so maybe Miranda does too? They are also fairly sure that Miranda's mixed surface is a result of heat from gravitational tidal forces, not just from the planet, but from its fellow moon Umbriel. These forces could have melted different parts of the icy surface, but a rival theory is that Miranda was smashed apart by a impact with another body long ago.

Because Voyager made such a fleeting visit to Uranus, it only managed to see, at best, half the surfaces of the moons. Each of them has large chunks that still remain unseen to human or robotic eyes. By settling into a steady orbit around the planet, Uranus Pathfinder will be in position to gradually map the entirety of all the moons, such as Ariel, which is 1,160 kilometres (720 miles) across, yet only 35 per cent of its surface has been seen in any detail. 27 moons of Uranus have been found so far, but Uranus Pathfinder could find many more tiny satellites too small and faint to be located easily.

In truth, we will only understand Uranus better by returning with a probe to enter orbit. "We have many mysteries to answer about this planet that can only be resolved by sending another mission," says Arridge. Learning about Uranus can also tell us about a certain breed of extra-solar planet. These are similar in size to Uranus and its nearby twin Neptune, but they're much closer to their stars than our ice giants are. "We've found hundreds of these planets orbiting stars other than our Sun," says Arridge. "We have a real need to properly understand these planets in our own Solar System, so that we can correctly interpret these new results from exoplanets." ■

> "Like the moons of Jupiter and Saturn, the natural satellites of Uranus are just as spectacular as their parent planet"

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The Chandra X-ray Observatory took this image of NGC 6240 with its accompanying gas cloud in both optical and X-ray wavelengths

Searing gas cloud

This giant cloud of blistering-hot gas is a snapshot of the creation of the universe

About 400 million light years away in the constellation Ophiuchus, the serpent-bearer, is the galaxy NGC 6240. It's the remnant of a galactic merger between two smaller galaxies a similar size to the Milky Way, and the resulting interaction has stirred up a huge cloud of gas.

This gas has enveloped the object and has a mass of 10 billion Suns. It's about 300,000 light years in diameter and glows hot in X-ray and infrared, with a temperature of over 7 million degrees Celsius (12.6 million Fahrenheit). The dynamics of the gas cloud have caused a sudden boom of new stars, born in great bursts over the last 200 million years. The merger should eventually lead to the formation of a single elliptical galaxy millions of years from now.

It's an event that was common in the early universe but is much rarer now, so NGC 6240 is a bit of a hot spot for observation among astronomers.

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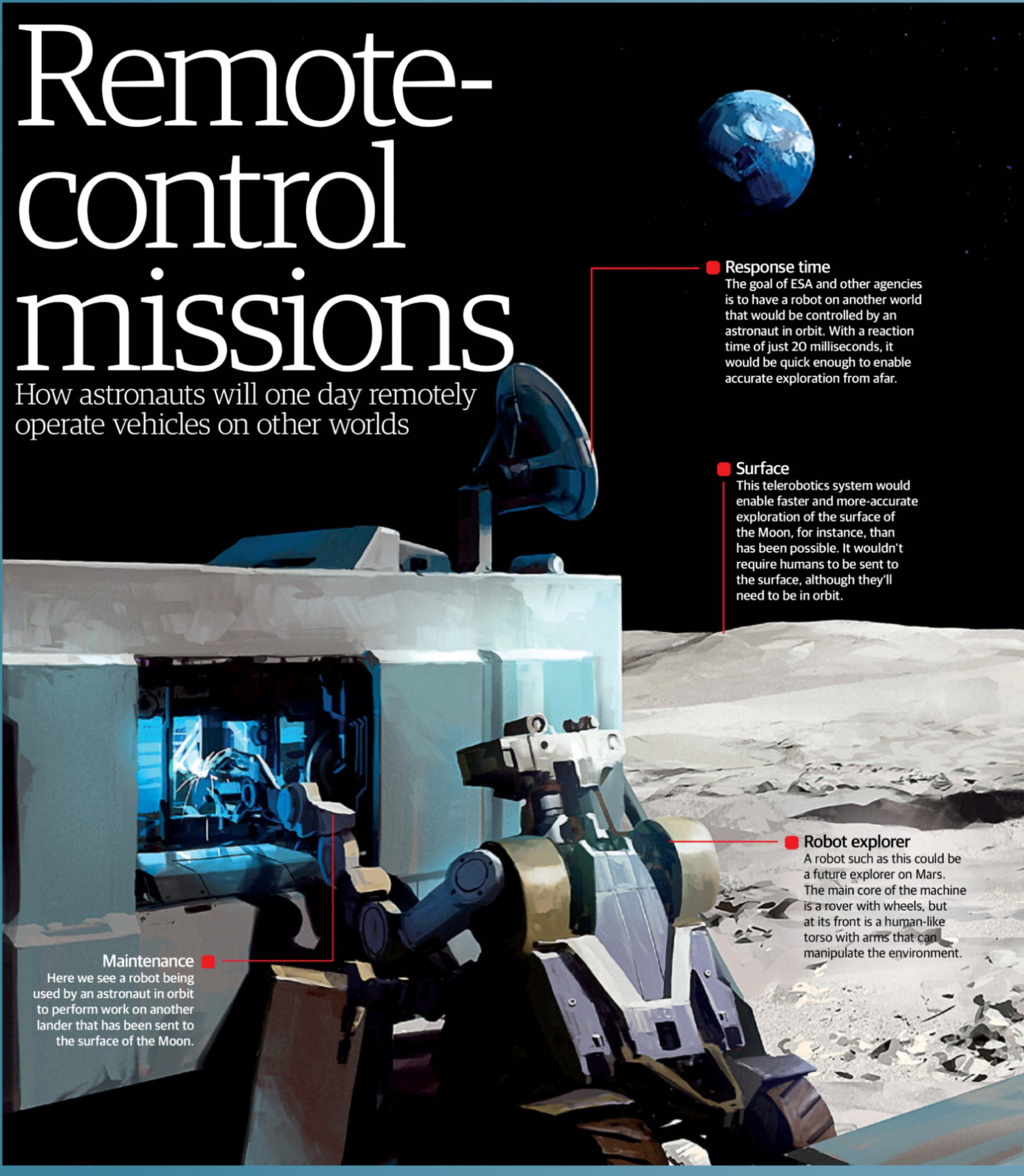
Remote-control missions

How astronauts will one day remotely operate vehicles on other worlds

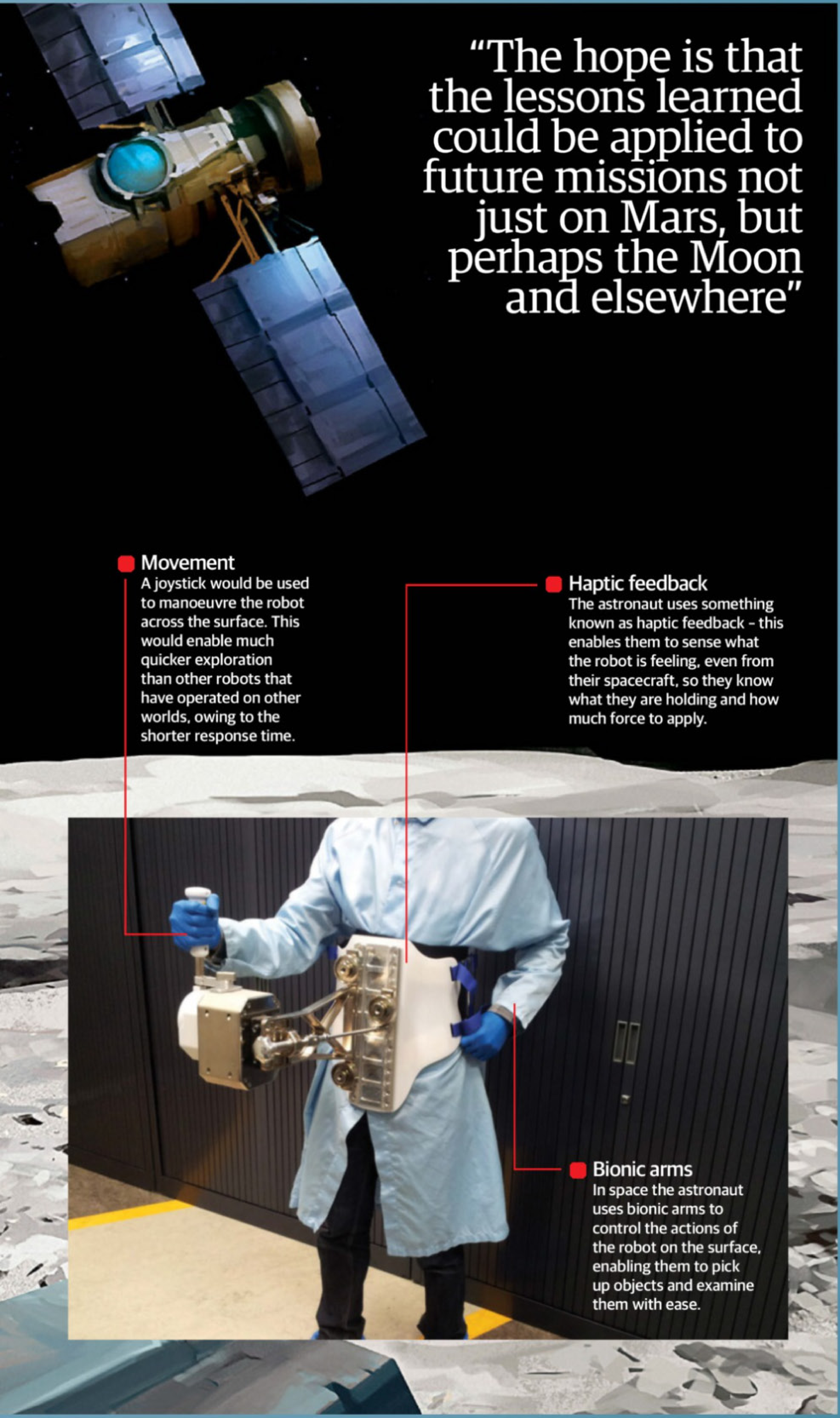


Response time
The goal of ESA and other agencies is to have a robot on another world that would be controlled by an astronaut in orbit. With a reaction time of just 20 milliseconds, it would be quick enough to enable accurate exploration from afar.

Surface
This telerobotics system would enable faster and more-accurate exploration of the surface of the Moon, for instance, than has been possible. It wouldn't require humans to be sent to the surface, although they'll need to be in orbit.

Robot explorer
A robot such as this could be a future explorer on Mars. The main core of the machine is a rover with wheels, but at its front is a human-like torso with arms that can manipulate the environment.

Maintenance
Here we see a robot being used by an astronaut in orbit to perform work on another lander that has been sent to the surface of the Moon.



> “The hope is that the lessons learned could be applied to future missions not just on Mars, but perhaps the Moon and elsewhere”

Movement
A joystick would be used to manoeuvre the robot across the surface. This would enable much quicker exploration than other robots that have operated on other worlds, owing to the shorter response time.

Haptic feedback
The astronaut uses something known as haptic feedback – this enables them to sense what the robot is feeling, even from their spacecraft, so they know what they are holding and how much force to apply.

Bionic arms
In space the astronaut uses bionic arms to control the actions of the robot on the surface, enabling them to pick up objects and examine them with ease.

Arguably one of mankind's greatest achievements in space exploration has been landing the Curiosity rover on Mars. Here, a high-tech suite of instruments is being taken around the surface of the Red Planet by the advanced rover, providing unprecedented information about this world.

The mission has one noticeable limitation: because the rover is controlled from Earth, progress is fairly slow. While it has an average speed of 30 metres (98 feet) per hour, it must wait for a signal from Earth before driving in a direction or carrying out a task. The return time is about 30 minutes for any communications to and from Mars, which means a seemingly easy task such as observing a rock, takes a lot longer than it would take a human.

While the ultimate goal is to have humans walk and work on the surface of worlds like Mars, a short-term solution could be the use of astronauts in the vicinity to control vehicles on the surface. This is known as telerobotics. Think of how you might operate a remote-controlled toy car on Earth – because you are within a short distance, your actions on the controller are instantly replicated by the car.

The same could be the case for astronauts in orbit around a planet or moon. They would be close enough that their actions on a space-based remote control would be emulated near-instantly by a rover on the surface below. By sending robots to various locations on an object's surface, scientists could explore vast regions without leaving their spacecraft.

With this in mind, ESA has designed systems that can be used by astronauts to remotely operate vehicles. In the first tests, astronauts will be controlling robots on Earth, but the hope is that the lessons learned could be applied to future missions not just on Mars, but perhaps the Moon and elsewhere as well.

On 12 August 2014 a European-built cargo ship, known as ATV-5 (Automated Transfer Vehicle), docked with the ISS. On board it carried an important piece of cargo related to telerobotics – a body-mounted joystick that will be used by astronauts to control a robot on Earth.

The joystick uses touch-based feedback, enabling the user to finely and accurately move a robot, as well as react to any obstacles in an environment. It's mounted to the body of an astronaut, who is in turn attached to a stationary object on the ISS.

The aim of the joystick is to provide astronauts with a remote sense of touch, to give them the greatest degree of control possible over the robot. While the joystick is used mostly for movement, eventually astronauts will have access to a bionic arm of sorts that emulates an actual arm on a robot.

By reaching their own arm out and moving it, the robot will do the same. A small hand on the end of the arm will enable them to use the robot to pick up objects such as rocks. Force feedback on the arm – known as haptic technology – will let the user know what sort of object they are holding and how much force they can apply without it breaking.

These technologies are part of the Multi-Purpose End-to-End Robotic Operation Network (METERON) initiative, which is investigating telerobotics for space. It may be innovative systems like this that enable future astronauts to explore other worlds like never before.

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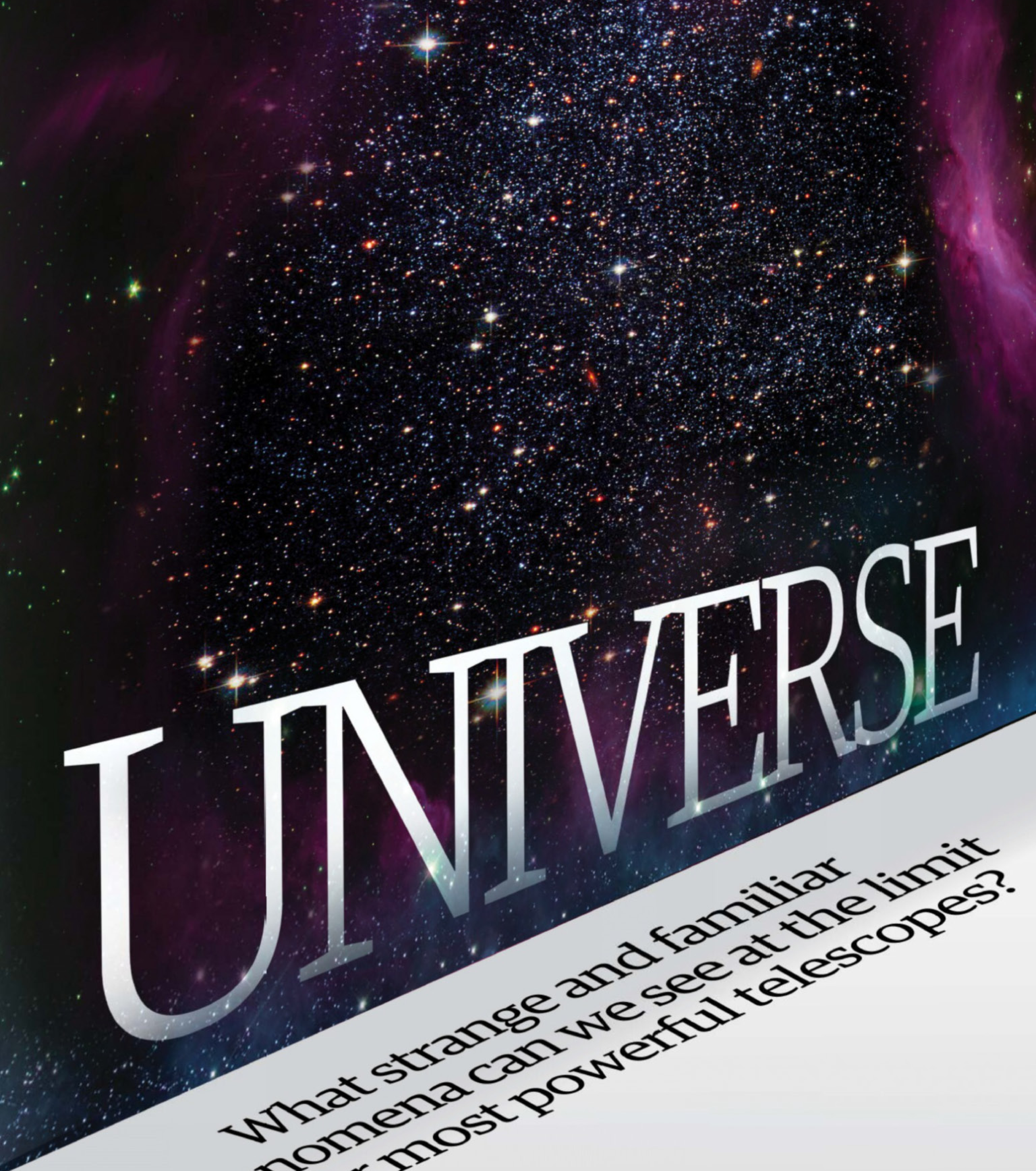


UNIVERSE

What strange and familiar phenomena can we see at the limit of our most powerful telescopes?

In December 1995 astronomers using the Hubble Space Telescope began a remarkable experiment. Turning the telescope's powerful gaze on an apparently empty patch of sky in the constellation Ursa Major, they let its cameras soak up rare photons of light for more than 100 hours. The resulting image revealed countless galaxies disappearing into the darkness – it would prove to be the first of several *Hubble Deep Field* images. These awe-inspiring pictures have revealed the remote universe in ever-increasing detail.

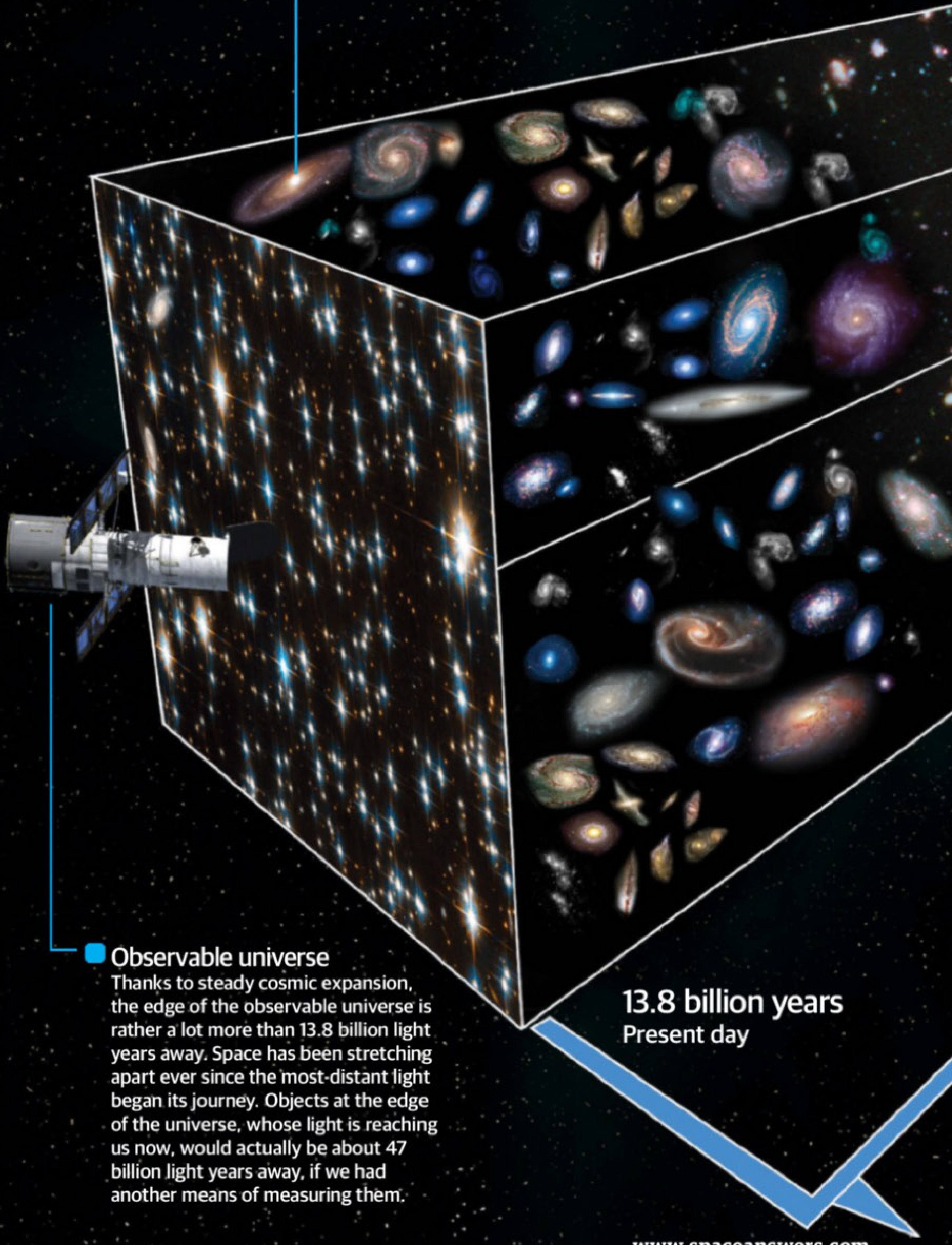
From our location on Earth, the entire cosmos is an enormous time machine – light might be the fastest thing there is, but even its tremendous top speed of 300,000 kilometres (186,400 miles) per second dwindles in comparison with the vast distances of remote stars and galaxies. Everywhere we look in distant space, we're also looking back in time and the more powerful our telescopes get, the further back we can see.

With larger telescopes and ever-increasing exposures, we might expect to go on seeing more and more galaxies stretching on forever – but the physics of the cosmos put a limit on our ambitions. Overwhelming evidence suggests the universe was born in the Big Bang some 13.8 billion years ago and has been expanding ever since – no light could have started its journey before that time. So, from our point of view, Earth is at the centre of a bubble of expanding space and time that stretches out in every direction, to a boundary where light has only just had time to reach us – the so-called observable universe. Fortunately, most astronomers view the cosmic time machine not as a barrier but as a hugely informative tool, as Dr Daniel Mortlock of Imperial College London explains. "The reason people put so much effort into finding such distant objects isn't really because they're far away. Rather, it's because we see them as they were so long ago. As far as we can tell the universe is broadly the same wherever we look, so what these observations really do is help us understand how the universe was billions of years ago. In some ways, this sort of astronomy is rather like archaeology."

Searching for such distant objects is a huge challenge, as Professor Steve Finkelstein of the University of Texas, Austin, knows well: "These galaxies are incredibly distant, so no matter what we do, its going to take a long time to observe them. Even the brightest galaxies we can observe, less than a billion years from the Big Bang, are very faint. The faintest star your eye can see is an incredible 40 million times brighter than the brightest distant galaxy. That's why we need very large telescopes."

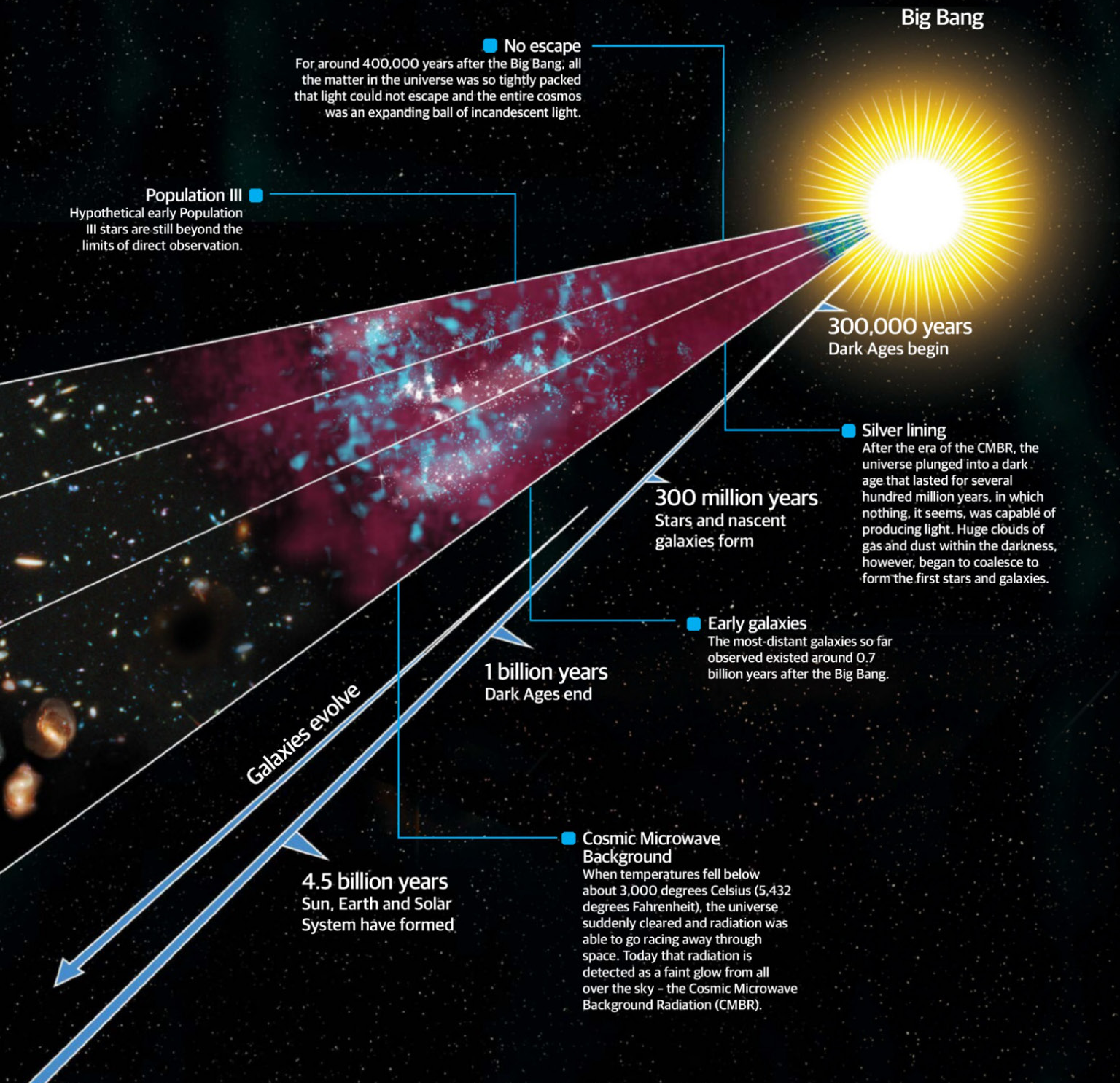
Cosmic expansion has another important affect on our view of distant objects – as space has stretched, it has also stretched the wavelengths of light rays travelling through it – the effect known as Doppler shift. "Due to the expanding universe, all of the ultraviolet and visible light from these galaxies are Doppler-shifted into the infrared," continues Professor Finkelstein. "While we can observe some of these wavelengths from the ground, the technology is in its infancy." What's more, Earth's own atmosphere glows at many infrared wavelengths, swamping out the faint rays from distant objects and obscuring them from observation.

Towards the edge



Light-stretching
As the microwave background's name implies, the long journey across expanding spacetime has stretched out the once-incandescent light into the much-longer wavelengths of low-energy microwaves.

Observable universe
Thanks to steady cosmic expansion, the edge of the observable universe is rather a lot more than 13.8 billion light years away. Space has been stretching apart ever since the most-distant light began its journey. Objects at the edge of the universe, whose light is reaching us now, would actually be about 47 billion light years away, if we had another means of measuring them.



No escape
For around 400,000 years after the Big Bang, all the matter in the universe was so tightly packed that light could not escape and the entire cosmos was an expanding ball of incandescent light.

Population III
Hypothetical early Population III stars are still beyond the limits of direct observation.

Silver lining
After the era of the CMBR, the universe plunged into a dark age that lasted for several hundred million years, in which nothing, it seems, was capable of producing light. Huge clouds of gas and dust within the darkness, however, began to coalesce to form the first stars and galaxies.

Early galaxies
The most-distant galaxies so far observed existed around 0.7 billion years after the Big Bang.

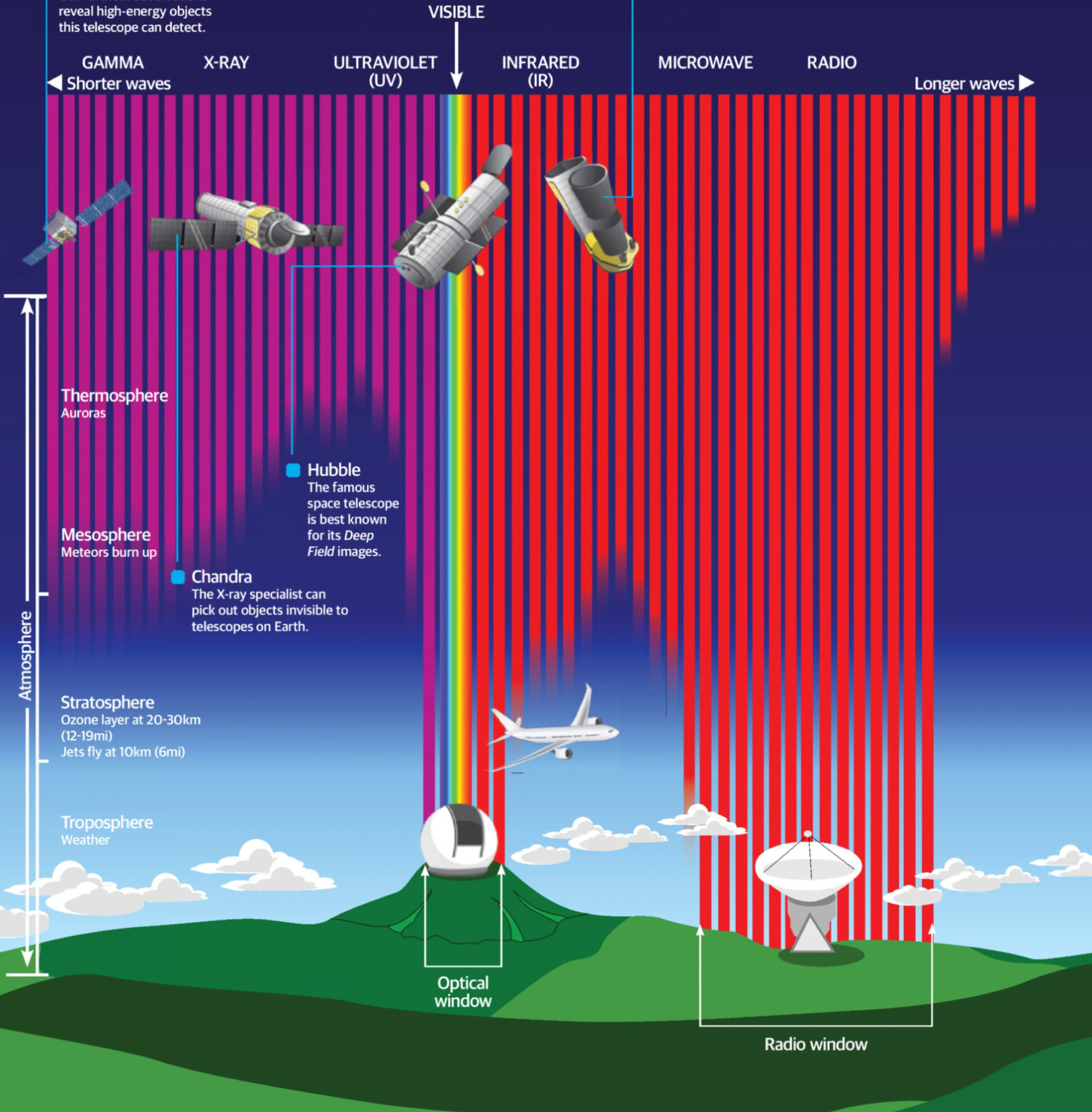
Cosmic Microwave Background
When temperatures fell below about 3,000 degrees Celsius (5,432 degrees Fahrenheit), the universe suddenly cleared and radiation was able to go racing away through space. Today that radiation is detected as a faint glow from all over the sky – the Cosmic Microwave Background Radiation (CMBR).

> "Even the brightest galaxies we can observe, less than a billion years from the Big Bang, are very faint"
>
> **Professor Steve Finkelstein, University of Texas**

Observing the edge

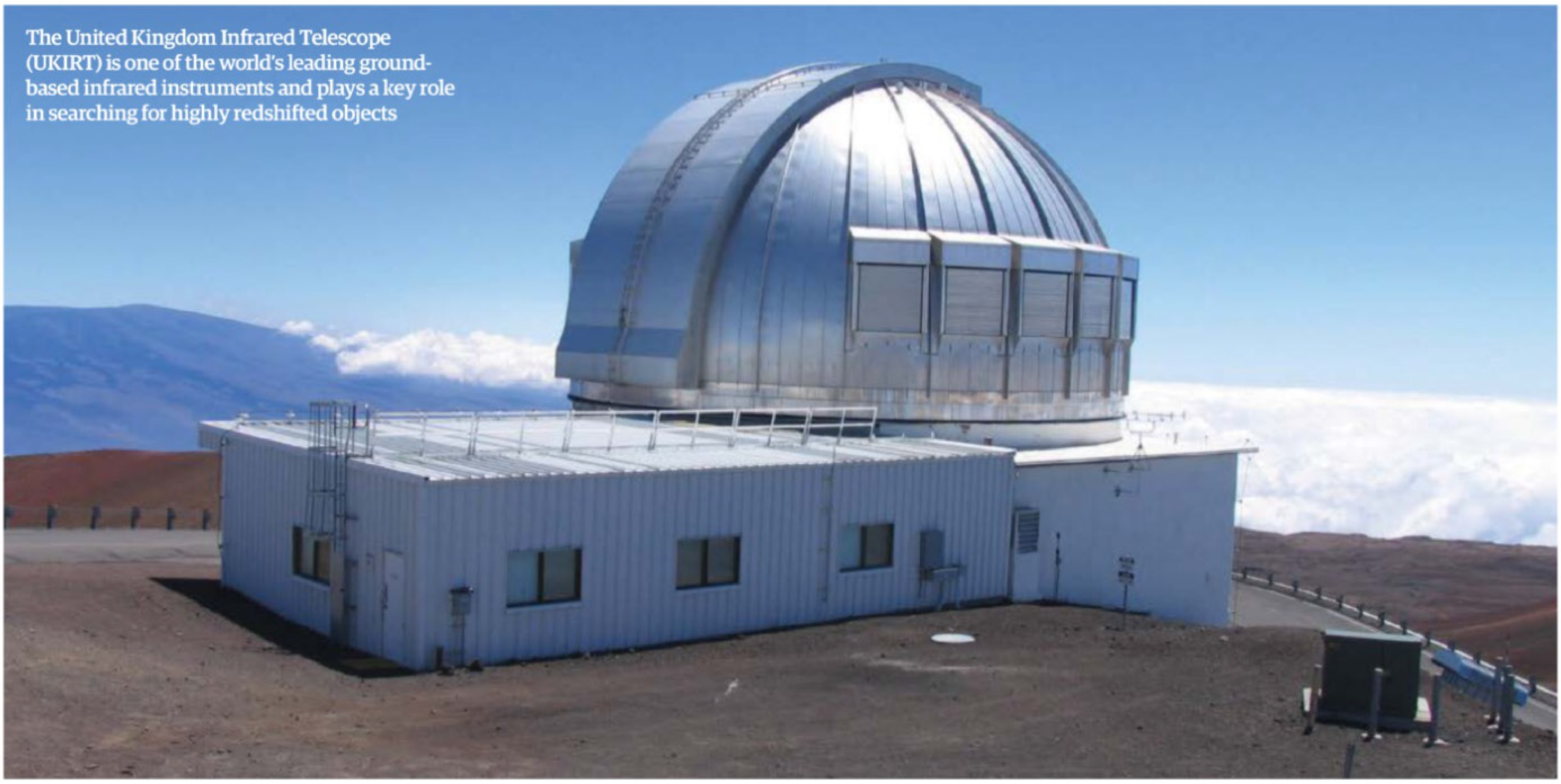
Fermi
Our furthest observations reveal high-energy objects this telescope can detect.

Spitzer
This infrared telescope often works in conjunction with Hubble to take the deepest snapshots of space.



Hubble
The famous space telescope is best known for its *Deep Field* images.

Chandra
The X-ray specialist can pick out objects invisible to telescopes on Earth.



The United Kingdom Infrared Telescope (UKIRT) is one of the world's leading ground-based infrared instruments and plays a key role in searching for highly redshifted objects

The general shift of light from distant galaxies into redder, longer wavelengths is an important hint for astronomers hunting the earliest galaxies. Deep-red galaxies appear as blobs just a few pixels across in long-exposure Hubble images, but are often seen close to gravitational lenses. These are natural cosmic zoom lenses created when a massive galaxy cluster closer to Earth distorts and intensifies light from more-distant objects.

In 2013, Professor Finkelstein and his team discovered the most-distant galaxy yet identified, catalogued z8_GND_5296, as part of a special project using the infrared capabilities of the Hubble Space Telescope. "Spectral observations from Hawaii's enormous W.M. Keck Observatory soon confirmed an immense speed of retreat, plus a huge distance corresponding to an origin about 700 million years after the Big Bang," he explains. "But that wasn't all: when we used our observations to infer the physical properties of this galaxy, we found it was forming stars at an incredible rate. Galaxy z8_GND_5296 is turning an amount of gas equal to 300 times the mass of our Sun into new stars every year – that's a rate of around 150 times that of the Milky Way."

Researchers expected to see stars forming at an accelerated rate in such distant young galaxies, but z8_GND_5296 was still creating stars about 30 times faster than they had anticipated. Finkelstein's team have shown there are many similar galaxies in the early universe, "Simulations of the distant universe don't have such galaxies in them, so by observing them we're learning something incredibly new about the distant universe."

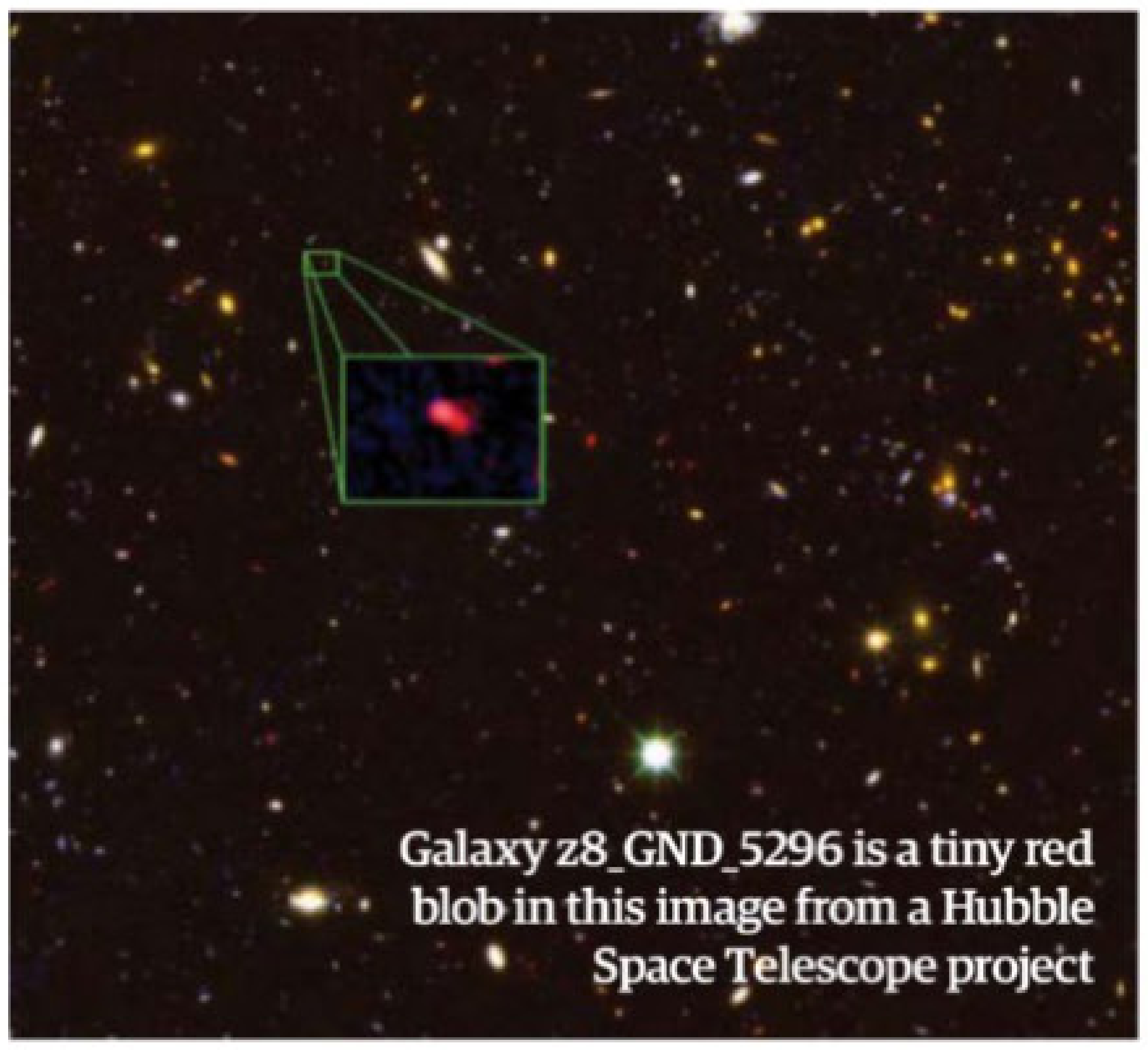
While astronomers like Professor Finkelstein focus on looking for entire galaxies in the early universe, they're not the only possible targets for astronomers hoping to probe the very edge of the cosmos. For instance Dr Mortlock and his colleagues concentrate on the search for quasars. These are active galactic nuclei in which the giant central black hole is swallowing up material from its surroundings and heating it up in the process. This results in an intensely bright central region that may be hundreds of thousands of times brighter than its parent galaxy.

> "If Population III stars exist, their light would be travelling from the very edge of the known universe"

"This incredible luminosity is also the reason we can see quasars so far away," explains Dr Mortlock. "Even the most-distant quasar known, ULAS J1120+0641, which is seen as it was when the universe was just five per cent of its current age of 13.8 billion years, is a relatively bright astronomical source. It's approximately 10,000 times brighter than normal galaxies at a similar distance."

Dr Mortlock's team identified the ULAS object as part of a near-infrared sky survey using the 3.8-metre (12.5-foot) United Kingdom Infrared Telescope (UKIRT) on Mauna Kea, Hawaii. "The universe has expanded by a factor of eight or so since the light we see from ULAS J1120+0641 was emitted, and the wavelength of this light has been stretched by the same amount. So, the ultraviolet light emitted from these quasars is now seen by us in the infrared part of the spectrum."

Surprisingly this distant object has turned out to closely resemble other, relatively nearby quasars: "It appears to have a very similar mix of elements and so broadly the same kind of spectrum. This makes it comparatively easy to determine the physical properties of this object and particularly the mass of the black hole. From the speed at which the gas is orbiting, we estimate that it has 2 billion times the Sun's mass. This is not the most-massive black hole known, but it is the earliest supermassive black hole that has been found."



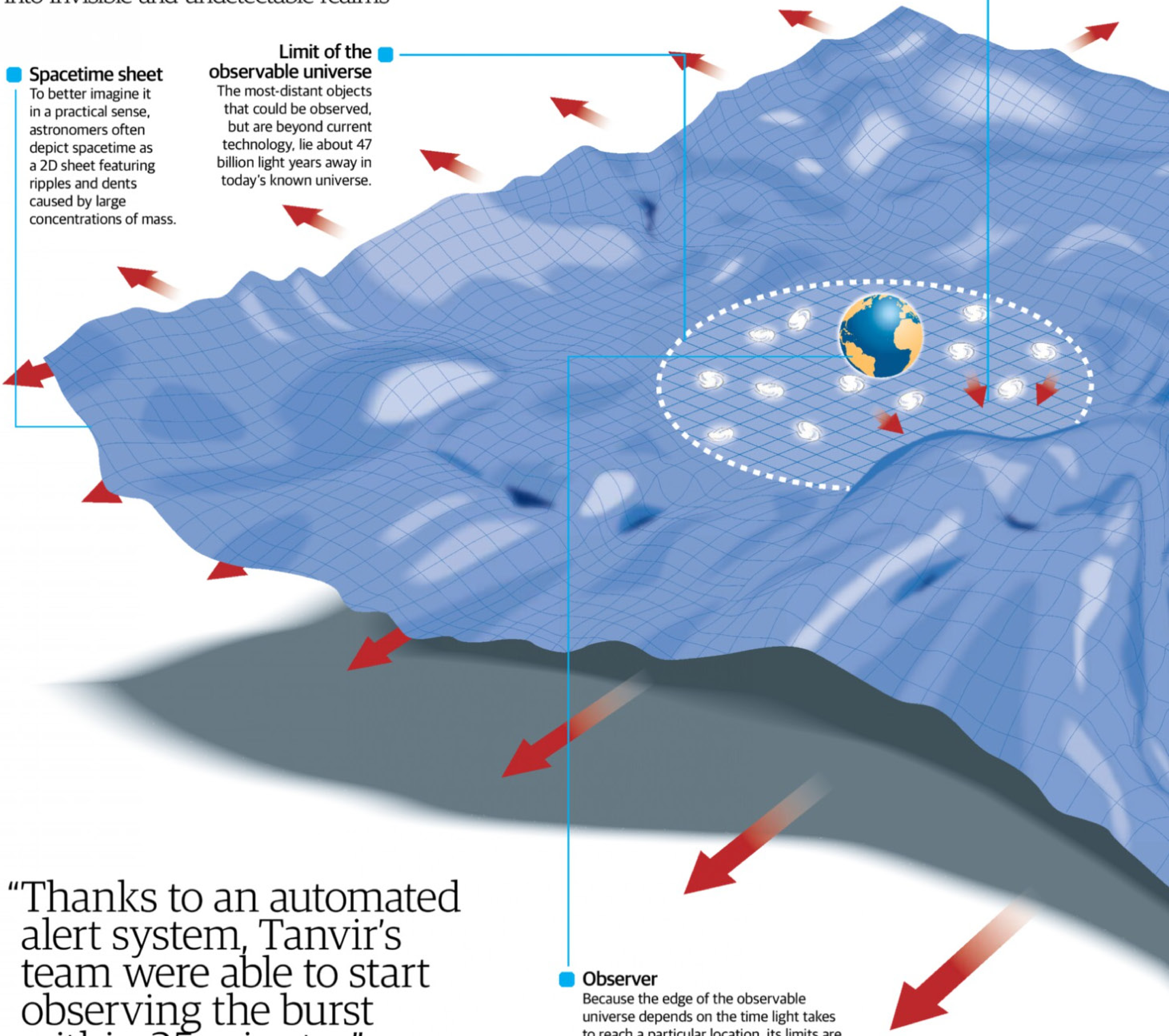
Galaxy z8_GND_5296 is a tiny red blob in this image from a Hubble Space Telescope project

The discovery of objects like the ULAS quasar has some important implications for ideas about the early universe. Dr Mortlock points out: "The mere existence of distant quasars – and particularly the supermassive black holes that power them – is something of a conundrum. Simple models of black hole formation and growth suggest that such monsters shouldn't have formed so quickly. It's no surprise to see them billions of years after the Big Bang, but 0.8 billion years doesn't seem like enough time."

Intriguingly, galaxies like z8_GND_5296 also seem to suggest an early universe that matured much more quickly than previously thought. Professor

Beyond the edge

The observable cosmos might mark the edge of what we can see, but it's not the edge of everything – the universe stretches away far beyond what we can see, into invisible and undetectable realms



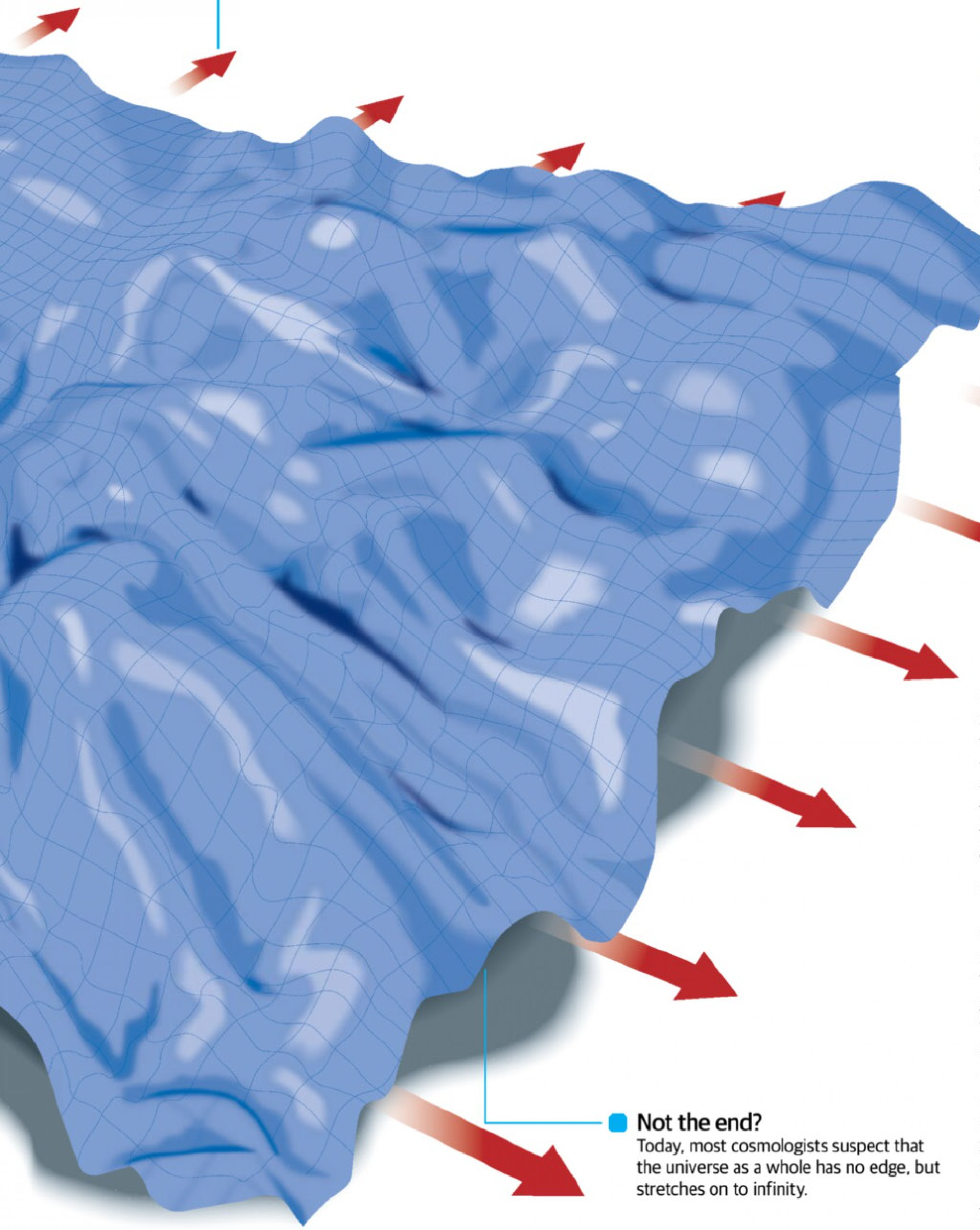
Dark flow within observable universe
Dark flow is a supposed large-scale pattern or drift in the motion of galaxy clusters, under the influence of forces beyond our observable universe.

Spacetime sheet
To better imagine it in a practical sense, astronomers often depict spacetime as a 2D sheet featuring ripples and dents caused by large concentrations of mass.

Limit of the observable universe
The most-distant objects that could be observed, but are beyond current technology, lie about 47 billion light years away in today's known universe.

Observer
Because the edge of the observable universe depends on the time light takes to reach a particular location, its limits are different for every observer.

"Thanks to an automated alert system, Tanvir's team were able to start observing the burst within 25 minutes"

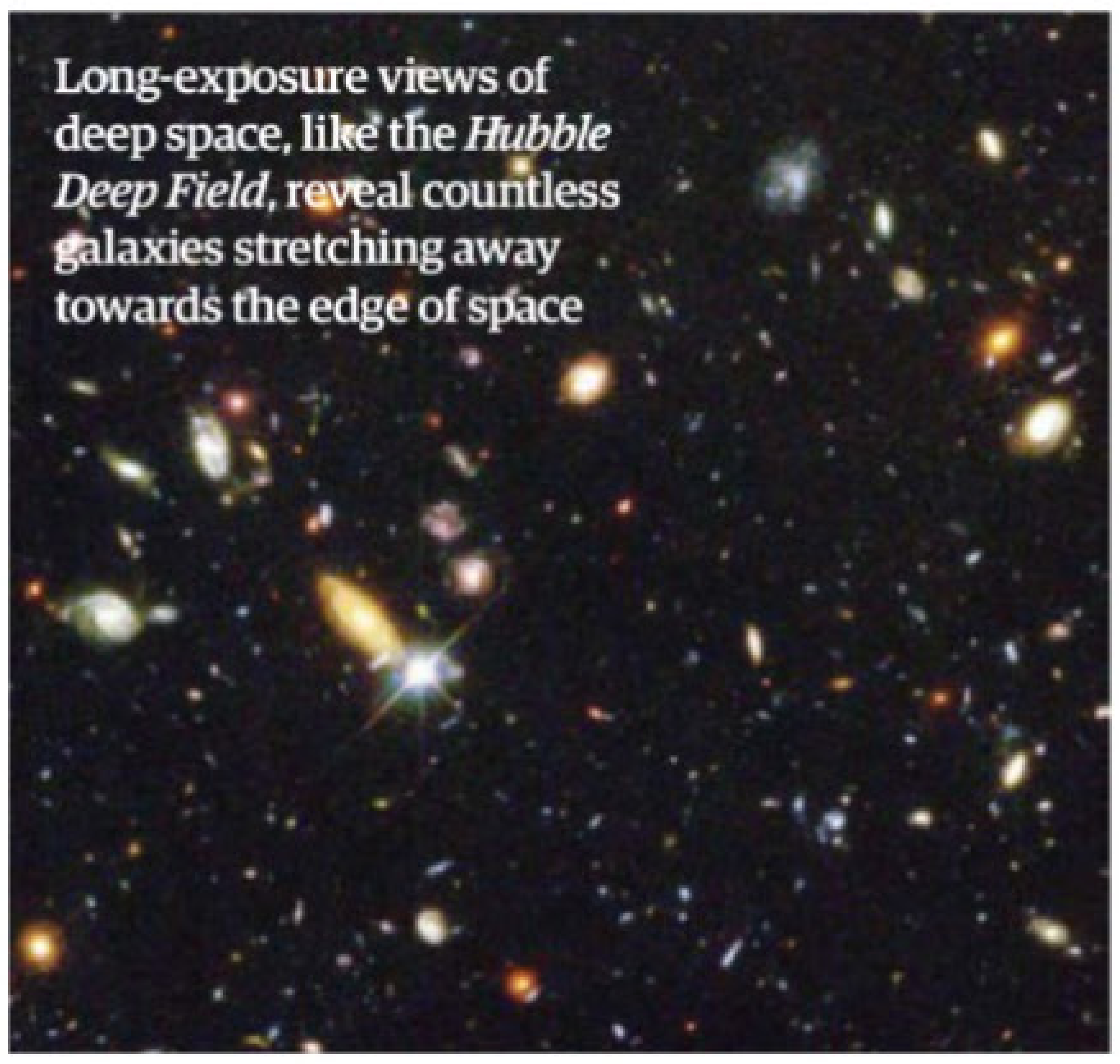


Source of dark flow

The cause of dark flow could be anything from a huge and dense super-supercluster of galaxies beyond our observable universe, to hypothetical warps in the large-scale structure of spacetime.

Not the end?

Today, most cosmologists suspect that the universe as a whole has no edge, but stretches on to infinity.



Long-exposure views of deep space, like the *Hubble Deep Field*, reveal countless galaxies stretching away towards the edge of space

Finkelstein's team used the infrared Spitzer Space Telescope to measure the spectrum of their record-breaking galaxy, discovering evidence for surprisingly large amounts of oxygen. "While it doesn't contain as many heavy elements (carbon, oxygen, iron) as our own, there are still significant amounts. This is surprising given how close it is to the Big Bang, since heavy elements had to be created in early generations of stars and that takes time."

So how could supermassive black holes and large amounts of heavy elements have formed so soon after the Big Bang? A solution might lie with a hypothetical early generation of short-lived stars whose primitive composition enabled them to break the upper limits of stellar mass seen in the present-day universe. These so-called Population III stars (with the mass of a thousand Suns or more) could have rapidly enriched the early universe with heavy elements, and also left-behind enormous black holes, to form the seeds of the first galaxies. If Population III stars exist, their light would be travelling from the very edge of the known universe and would be redshifted far more than even the most-distant known galaxies. As such, they're beyond the limits of current observing technology, but are a prime target for NASA's James Webb Space Telescope (JWST), the enormous infrared observatory currently scheduled for launch in 2018.

Another significant class of objects at the edge of the known cosmos is perhaps the most elusive of all – the intense but short-lived bursts of short-wavelength electromagnetic energy known as gamma-ray bursts (GRBs). First discovered in the 1960s, they have been the subject of huge speculation for several decades. "The luminous output is the equivalent of capturing the Sun's entire light output for its 10-billion-year lifetime as an ordinary star, saving it all up in a bottle, then releasing it in a single 30-second blast of light," explains Professor Derek Fox of Penn State University.

GRBs seem to fall into several distinct categories based on the strength and duration of their bursts. One major group, the so-called long-duration GRBs (for which the gamma-ray flash is longer than about two seconds) are thought to be produced during the deaths of massive stars.

Nial Tanvir of the University of Leicester explains further: "It seems that when some stars (perhaps those about 30 to 40 times the mass of the Sun) run out of fuel and end their lives, they collapse due to gravity. In the process of doing this they eject an extraordinarily powerful jet of plasma. It's thought this energy is ultimately converted into electromagnetic radiation, particularly energetic gamma rays, but also lower-energy light (X-rays, optical, infrared, radio). If the jet is pointing towards us, this results in an extremely bright initial flash followed by a fading afterglow."

Professors Tanvir and Fox have identified some of the most-distant GRBs so far detected, responding to rays initially detected by NASA's Swift Gamma-Ray Burst mission. "Satellites like Swift communicate new discoveries automatically to the ground, where the information is forwarded to observers around the world on a timescale of a few tens of seconds. From this point we have to decide quickly how interesting any given burst appears to be, and what telescopes might be able to make rapid observations," explains Professor Tanvir.

The most-distant confirmed burst is known as GRB 090423 – a designation that indicates its date of discovery on 23 April 2009. Thanks to an automated alert system, Tanvir's team were able to start observing the burst within 25 minutes, using the UKIRT. Fox's team soon added their own observations from the observatory's bigger neighbour, the 8.2-metre (27-foot) Gemini North Telescope. "For the furthest gamma-ray bursts, one doesn't get much clue about their distance from the gamma-ray data, so it's critical to make optical and infrared observations of the afterglow as soon as possible, preferably within an hour or so."

So, why optical and infrared? Professor Tanvir elaborates: "Neutral hydrogen, which is plentiful in the universe, is very effective at absorbing ultraviolet light. For very distant explosions, the cosmological redshift moves this wavelength all the way through the optical and into the infrared. Hence the signature of a distant GRB is that it's invisible in the optical but visible in the infrared. The step between visibility and invisibility is what gives us the redshift. In this case, we finally pinned down the [exact redshift value], corresponding to a distance of about 13.1 billion light years. In other words, GRB 090423 was a star exploding only about 630 million years after the Big Bang itself."

Remarkably, this record-breaking burst may even have been bettered just a few days later by another one, GRB 090429B. "The burst arrived at 1:30am," recalls Professor Fox. "My team was in charge of GRB work with the Gemini North telescope on Mauna Kea that night – we quickly saw that Swift had found an X-ray afterglow, but saw no optical or UV emission, so that meant we probably wanted to observe in the red and near-infrared bands to see if we had a high-redshift burst.

"Working with Professor Nial Tanvir and his colleagues, we found a relatively bright near-infrared afterglow with no optical light – bingo! The next night we requested further imaging and used it to confirm the fading of the source we had seen," Professor Fox continues. "That was the burst afterglow for certain, but sadly we were never able to get its spectrum."

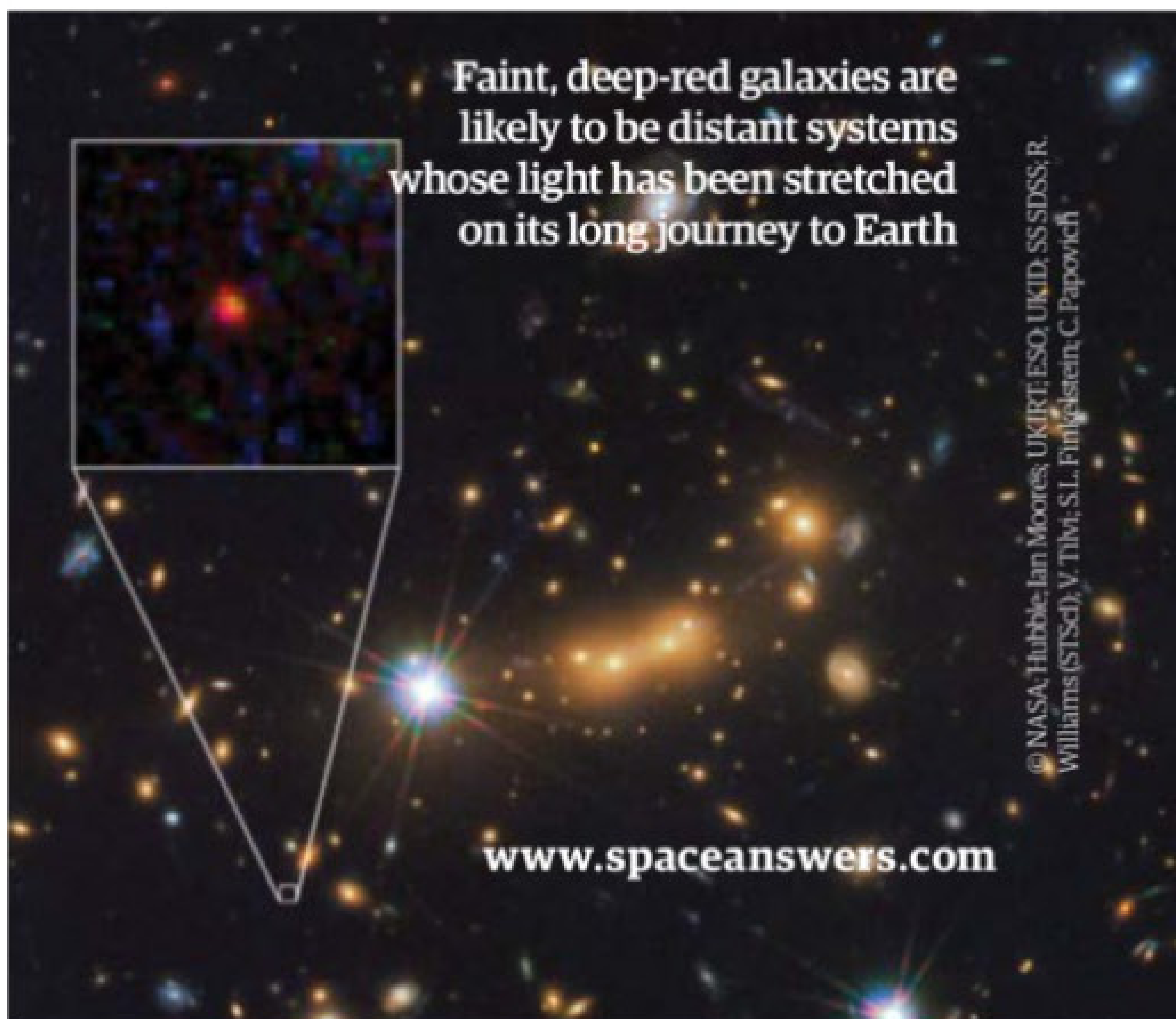
As a result, estimates of GRB 090429B's distance remain frustratingly imprecise, but the best estimates give it an even greater redshift value. This suggests that it exploded around 100 million years earlier than GRB 090423.

"Even limited information potentially has important consequences. For instance, the fact that none of the GRB host galaxies at [similar redshift values] has been detected by Hubble so far, suggesting that the large majority of this early star formation is happening in galaxies that are too small and faint for even Hubble to see."

The next few years surely promise to be an exciting time for researchers probing the edge of the observable universe. At the moment, these borderlands may resemble an old seafarer's map, filled with mysterious monsters we are only just beginning to understand. But the launch of the JWST will help bring the early galaxies and perhaps even the very first Population III stars into focus, giving us an unprecedented view both out into the depths of space and an essential glimpse back to the very beginnings of the cosmos. ■

At the heart of every quasar lies a supermassive black hole, feeding voraciously on its surroundings to create a brilliant disc of superhot matter that vastly outshines its host galaxy

An accepted model for the formation of many GRBs involves two narrow jets during the death of a massive star, channelling particles and radiation beams into space in a brilliant burst



Faint, deep-red galaxies are likely to be distant systems whose light has been stretched on its long journey to Earth

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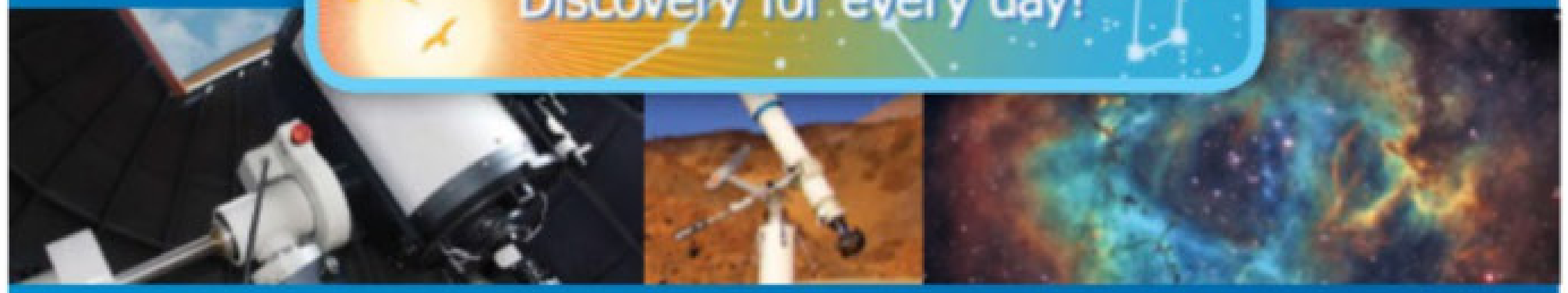

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All About… THE SHAPLEY SUPERCLUSTER

Introducing the most massive supercluster in the known universe, a dense collection of over 8,000 individual galaxies that are over 500 million light years from the Earth

Written by Laura Mears

All About... The Shapley supercluster

Galaxies rarely exist as isolated entities. As the universe expanded after the Big Bang, the distribution of matter was not entirely uniform, so instead of spreading out evenly, clumps grouped together. Mutual gravitational attraction gathered stars into galaxies, which in turn collected to form groups. These groups then associated into clusters, which came together to form superclusters. The universe became a web of densely compacted galaxies interspersed with vast voids, like a network of soap bubbles surrounded by matter and filled with empty space.

Our own Milky Way is part of the Local Group, a collection of 54 gravitationally interacting galaxies, including our nearest spiral neighbour Andromeda. The Local Group makes up part of the Virgo cluster, which in turn is part of a larger collection of around 47,000 galaxies, known as the Virgo supercluster. This measures a huge 110 million light years across.

Beyond our home supercluster, there are many others that we know of. The richly populated Coma supercluster contains over 3,000 galaxies, most of which are elliptical or lenticular in shape, and some of which are thought to be almost as old as the universe itself. It lies to the north of the plane of the Milky Way and can be observed unobscured, enabling astronomers to peer into the heart of the cluster as neighbouring galaxy groups begin to collide.

However, by far the most massive supercluster in the observable universe is Shapley, also known as the Shapley concentration. This supercluster is a collection of over 8,000 galaxies, with a total mass estimated at more than 10 million billion times that of the Sun. Many of the concentration's member clusters number among the richest and brightest in the sky.

The supercluster lies to the north of the constellation Centaurus and despite its massive scale was only identified relatively recently. It's over 500 million light years from the Earth and is in an awkward position for imaging, obscured by the stars and dust of the Milky Way.

In a project that began in the 1920s, Harlow Shapley and his colleagues at Harvard University charted the galaxies in the southern sky and identified an enormous elongated cloud in the direction of the constellation Centaurus.

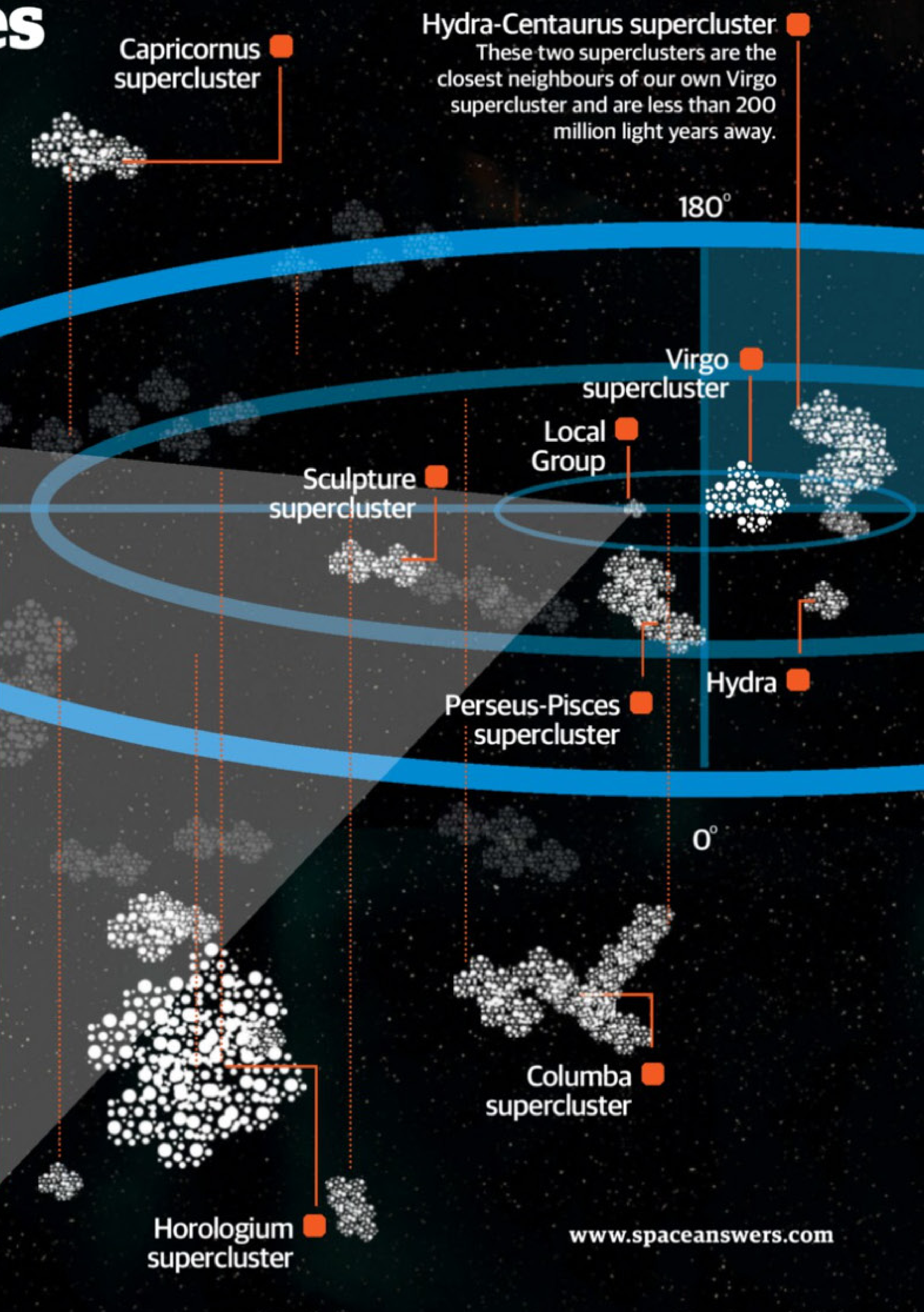
The supercluster remained largely unstudied for decades, but interest in the galaxies reignited in the 1980s after the discovery that a closer superstructure, Hydra-Centaurus, might be harbouring an entity known as the Great Attractor. This is a structure with a gravitational pull so huge that it's tugging on all of the galaxies in the surrounding area, including the Local Group, and by extension, the Milky Way.

Observations of the motion of galaxies in the surrounding area revealed a streaming current of movement in the direction of Centaurus, travelling at a speed of over 1.6 million kilometres (1 million miles) an hour. At the time it was predicted a pull this strong would require an entity containing 10^{16} times the mass of the Sun. However, as scientists peered through the dust using infrared, microwave and X-ray equipment, it became clear that the Hydra-Centaurus supercluster was nowhere near as massive as originally predicted. Then, several hundred million light years behind it, the even more massive Shapley supercluster came into view. ●

Nearby superstructures

Shapley eclipses closer superstructures and its pull can even be felt by the Milky Way

The observable universe surrounding the Milky Way is a patchwork of superclusters and voids. In the direction of the Shapley concentration, there are two other major collections of galaxies. The Coma supercluster is one of the richest and is positioned high above the plane of the Milky Way, enabling us a clear view into its heart. The Hydra-Centaurus cluster is the closest, lying right behind the centre of our galaxy, obscured by bright foreground stars and a cloud of dust.



These two superclusters are the closest neighbours of our own Virgo supercluster and are less than 200 million light years away.

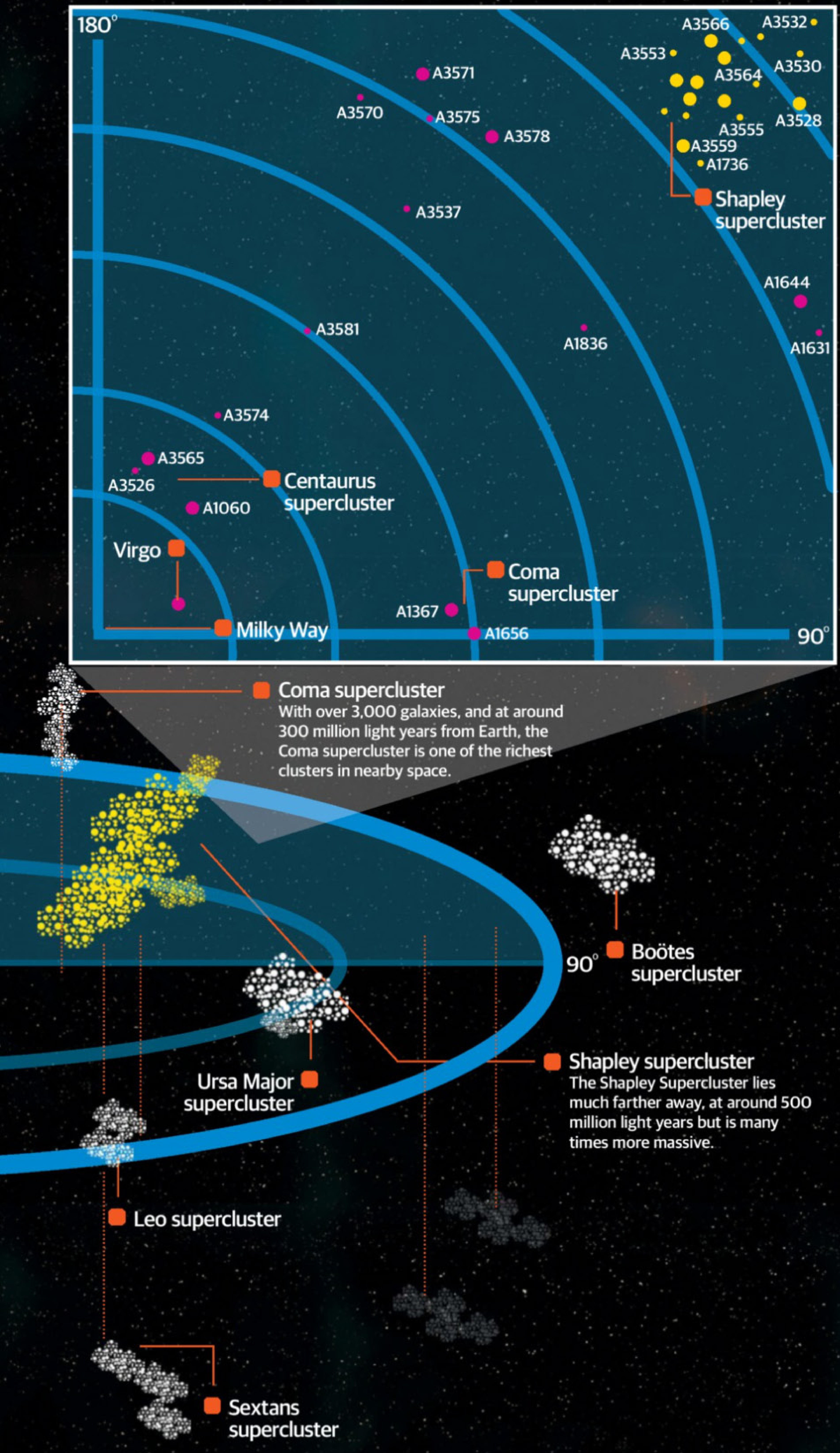
The structure of the universe

The Milky Way is part of the Virgo supercluster, so we are surrounded by other massive collections of galaxies

There are a few isolated galaxies in the universe, but the vast majority are bound together in groups. Each of these groups can have as many as 50 members and can span an area measuring several million light years across. Groups with more than 50 galaxies become clusters, either in their own right, or in combination with other neighbouring groups. Some measure tens of millions of light years in diameter.

The clusters in turn collect together in vast elongated filaments and large superclusters, bound by their own mutual gravity. Between them are cosmic voids, empty spaces containing just a tenth of the total matter density.

Shapley is the largest supercluster in the observable universe, but incredibly it too is dwarfed by something even more massive. The Hercules-Corona Borealis Great Wall is a filament (a galactic superstructure) measuring more than 10 billion light years in length and 900 million light years thick.



Coma supercluster
With over 3,000 galaxies, and at around 300 million light years from Earth, the Coma supercluster is one of the richest clusters in nearby space.

Shapley supercluster
The Shapley Supercluster lies much farther away, at around 500 million light years but is many times more massive.

By the numbers

10,000

The number of Milky Ways that would match the mass of the Shapley supercluster.

8,000

The minimum number of galaxies in the Shapley concentration.

500 million

The approximate distance in light years to the Shapley concentration from Earth.

3

25

The number of major galaxy clusters that make up the Shapley supercluster.

The core of Shapley is this many degrees in total length.

5

The total number of clusters that make up the main core of Shapley.

A look inside the galactic supercluster

This massive accumulation of galaxies provides a superb chance for astronomers to watch as individual clusters collide

The superstructures that make up the universe began to form early in its history, so as matter clustered together gravity took control, adding layer upon layer of complexity. Structures formed from the bottom up, starting small and gradually coalescing to form superclusters, like Shapley.

The core of the this huge concentration is marked by a dense string of five interacting galaxy clusters. They are bound to one another by gravity, and are like filaments described as Fingers of God. The three largest members are all listed in the Abell catalogue alongside some of the most-densely populated galaxy clusters in observable space.

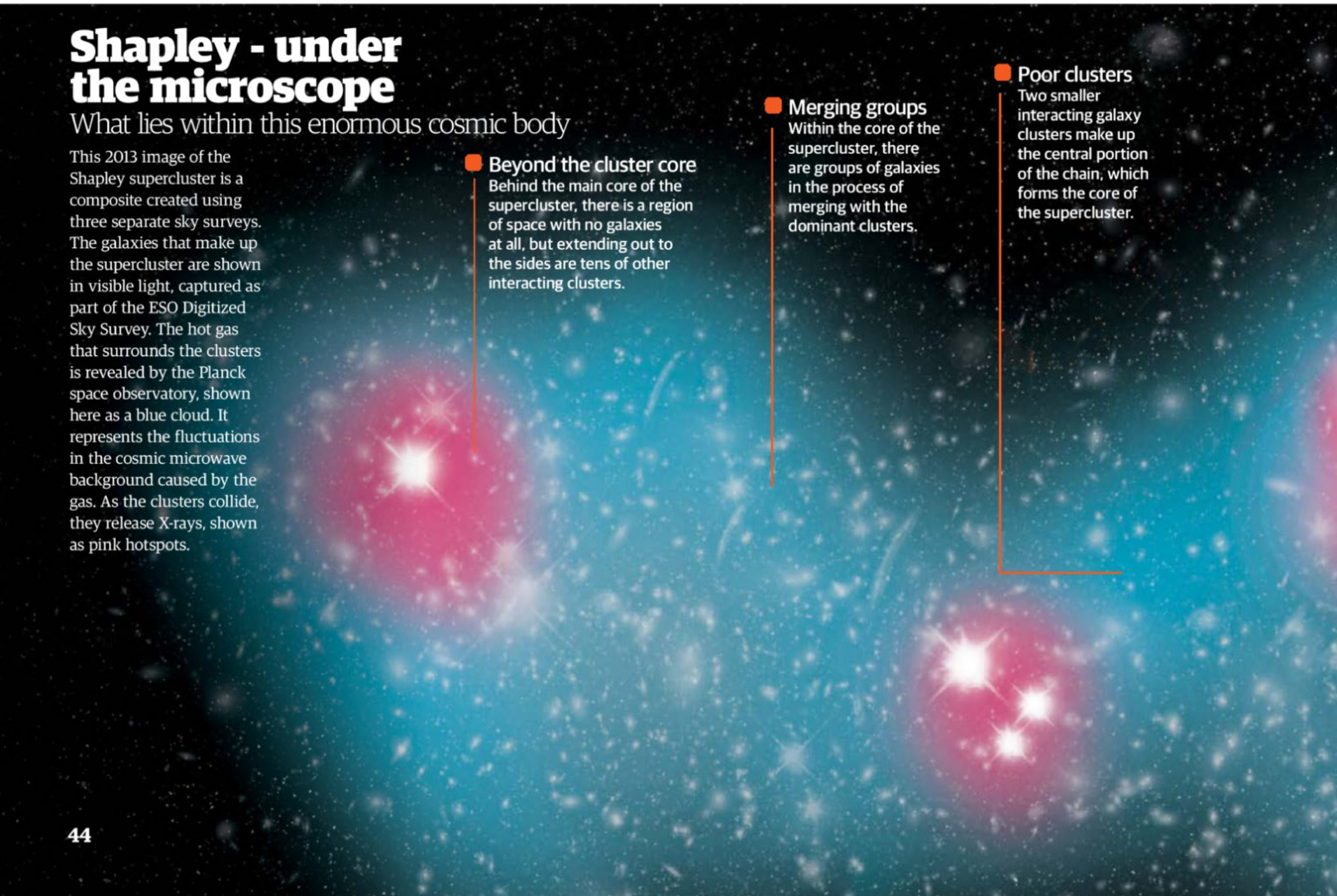
Like other rich clusters, these three each have a concentrated central core, containing older elliptical and lenticular galaxies, filled with ageing orange and red stars. Around the edges are the more-structured spiral galaxies, containing young, hot, blue and white stars.

This central strip of interacting clusters offers an opportunity to observe the interactions at the heart of a supercluster on an unprecedented scale. As galaxy clusters merge, they release huge amounts of energy and when viewed in the X-ray spectrum, bright points are visible at the centres. The two very largest clusters, A3558 and A3528, are the brightest visible here, but each is in a different stage of its lifecycle.

At the core of a supercluster, galaxy clusters become trapped in a mutual gravitational dance, so eventually members begin to collide with one another. In the region surrounding cluster A3558 the chain is fragmented and emissions are split into numerous distinct clumps. It's thought that at some point in the past, a smaller galaxy cluster struck the A3558 cluster

Shapley - under the microscope

What lies within this enormous cosmic body



This 2013 image of the Shapley supercluster is a composite created using three separate sky surveys. The galaxies that make up the supercluster are shown in visible light, captured as part of the ESO Digitized Sky Survey. The hot gas that surrounds the clusters is revealed by the Planck space observatory, shown here as a blue cloud. It represents the fluctuations in the cosmic microwave background caused by the gas. As the clusters collide, they release X-rays, shown as pink hotspots.

Beyond the cluster core
Behind the main core of the supercluster, there is a region of space with no galaxies at all, but extending out to the sides are tens of other interacting clusters.

Merging groups
Within the core of the supercluster, there are groups of galaxies in the process of merging with the dominant clusters.

Poor clusters
Two smaller interacting galaxy clusters make up the central portion of the chain, which forms the core of the supercluster.

and the two underwent a dramatic merger, producing shockwaves that rippled through the galaxies.

In contrast, A3528 is much less broken up. It's similar in size and scale to A3558, but the galaxies are arranged into far fewer groups. There are four major clumps, organized into two interacting pairs, each on an eventual course for collision.

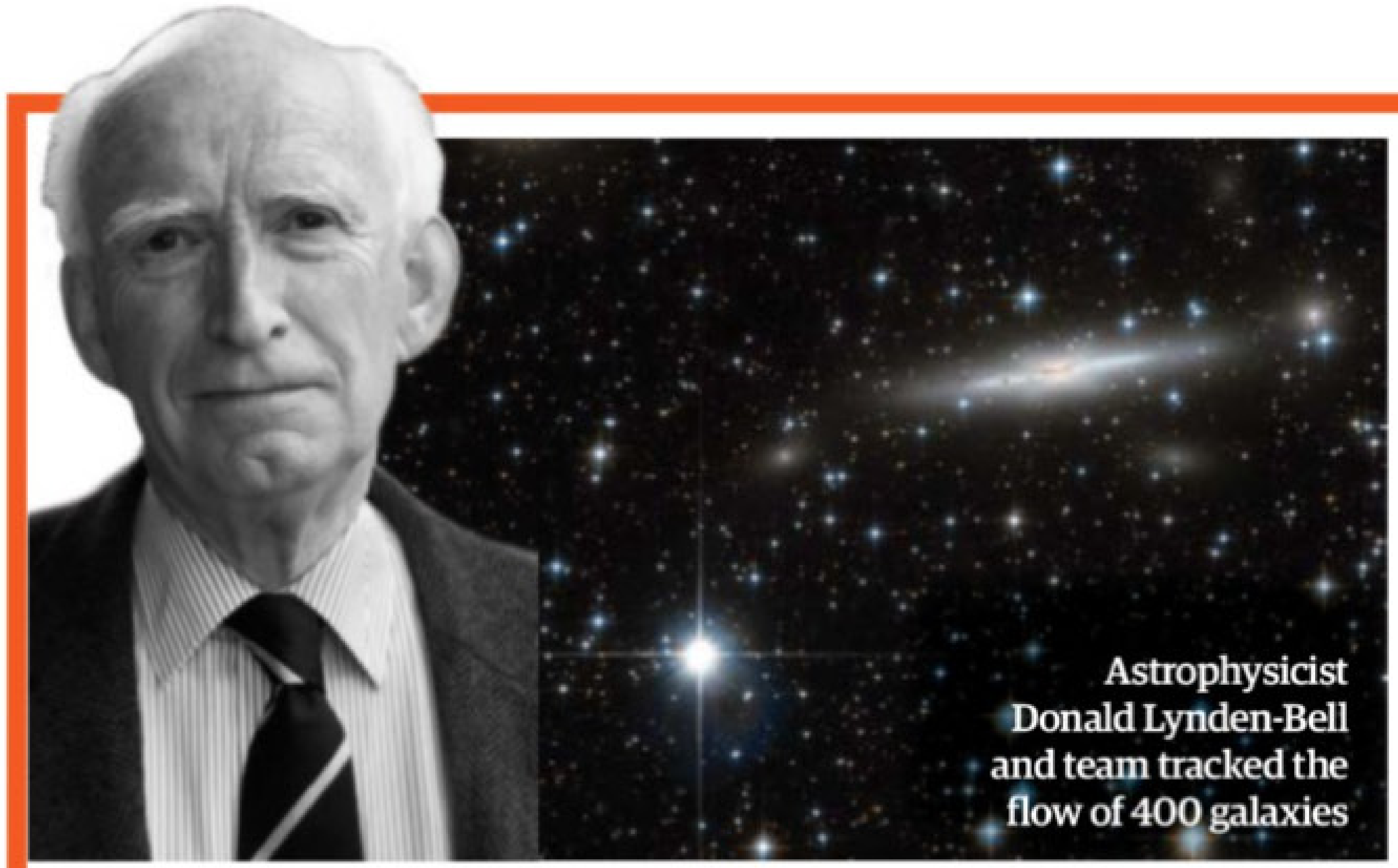
Around this central core, there are tens of other rich Abell clusters, but identifying the limits of the superstructure has been difficult, so some scientists suspect it extends much further into space than we can see currently, connected by thin filaments of galaxies and gas.

The Shapley concentration is still changing as intergalactic winds move through the supercluster, channelling matter towards its core, so the future of the structure is unknown. Its elongated shape could represent the seed of a new filament, a long thread that will continue to extend outwards into space. Alternatively, the clusters might continue to collapse, drawing in more galaxies from the edges.

Either way, the Shapley concentration is truly massive and even today has a measurable affect on its surroundings. The combined gravitational pull of a supercluster is intense, so the effects can be observed over vast distances.

The supercluster is even located behind the proposed location of the Great Attractor, an as-yet-unidentified entity of unprecedented scale, responsible for the streaming flow of galaxies in the direction of Centaurus. As astronomers continue to unravel the mystery of the Great Attractor, interest in the Shapley concentration is growing, so more-powerful instruments will enable us to probe even deeper into its heart. ●

> "It extends much farther into space than we can see"



Astrophysicist Donald Lynden-Bell and team tracked the flow of 400 galaxies

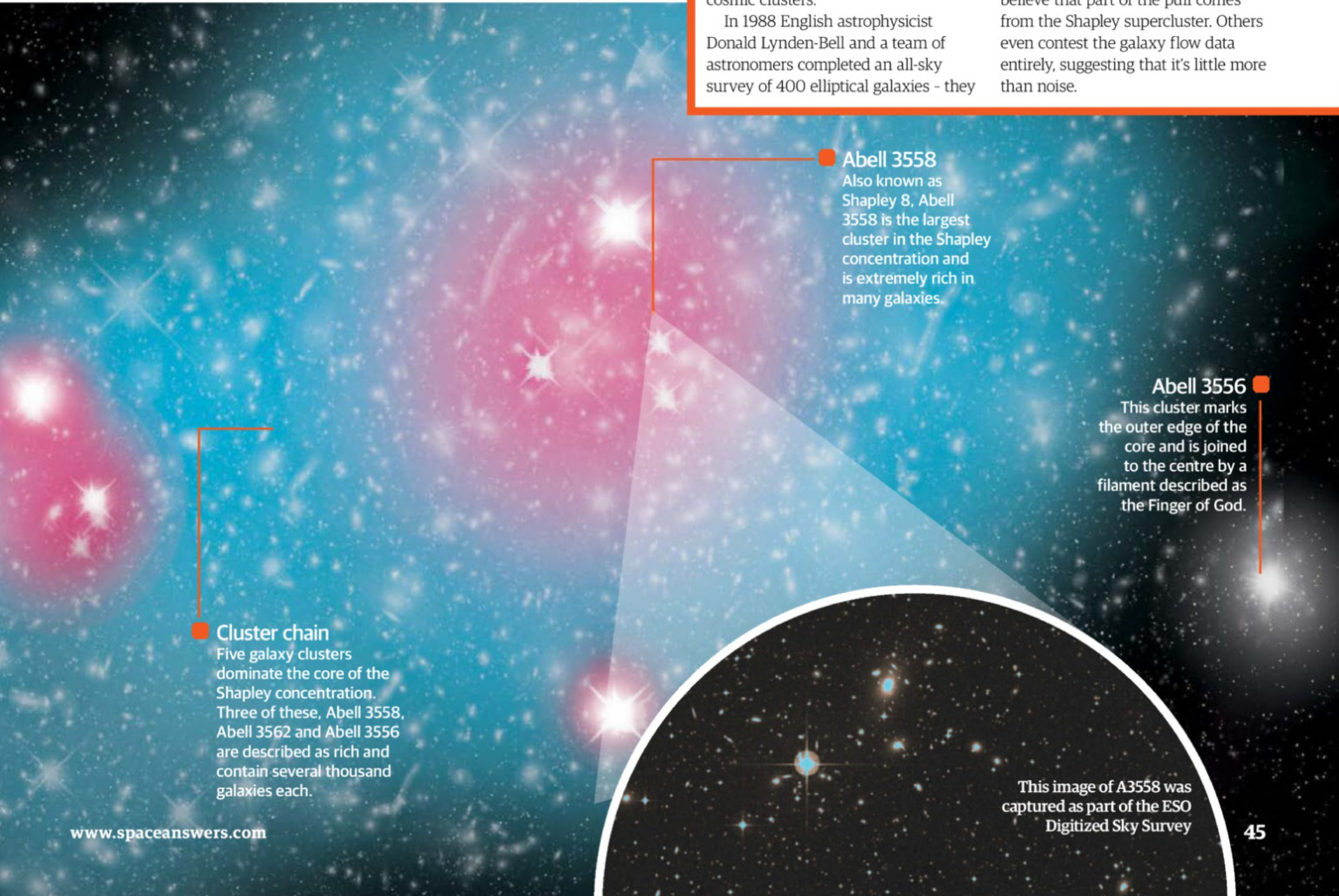
The Great Attractor

Is something really pulling us towards Centaurus?

When in 1929 Edwin Hubble demonstrated that the universe is expanding, he presented the idea that galaxies expand away from one another uniformly, like raisins in an infinite rising loaf of bread. However, this Hubble flow theory is distorted by gravitational attraction, so peculiar motions appear as passing galaxies interact. This diverts their course and enables them to group together in cosmic clusters.

In 1988 English astrophysicist Donald Lynden-Bell and a team of astronomers completed an all-sky survey of 400 elliptical galaxies - they found there was a serious deviation in their expected flow. Several galaxy clusters in the region of Centaurus appeared to be circling an invisible drain, moving towards an apparently great mass at a speed of several hundred kilometres per second.

Dubbed the Great Attractor, the source of the pull is still unknown. Some scientists argue that it's evidence of a multiverse, while others believe that part of the pull comes from the Shapley supercluster. Others even contest the galaxy flow data entirely, suggesting that it's little more than noise.



Abell 3558
Also known as Shapley 8, Abell 3558 is the largest cluster in the Shapley concentration and is extremely rich in many galaxies.

Abell 3556
This cluster marks the outer edge of the core and is joined to the centre by a filament described as the Finger of God.

Cluster chain
Five galaxy clusters dominate the core of the Shapley concentration. Three of these, Abell 3558, Abell 3562 and Abell 3556 are described as rich and contain several thousand galaxies each.

This image of A3558 was captured as part of the ESO Digitized Sky Survey

Observing the Shapley supercluster

The largest collection of galaxies in the observable universe has been probed in multiple wavelengths

The Shapley supercluster was first observed in 1930 by Harlow Shapley, an astronomer working at Harvard University. He identified the structure in photographic plates obtained from the Bruce telescope in South Africa, describing it as "a cloud of galaxies in Centaurus that appears to be one of the most populous yet discovered". Amazingly, Shapley wasn't even looking at the entire supercluster – what he saw was the faint, elongated cloud of its densely clustered core.

By the 1970s, X-ray emissions had been detected in Shapley 8, or A3558, the largest of the clusters. By 1989, several groups were searching for the Great Attractor, an enormous mass theorised to be located in the direction of Centaurus. The UK Schmidt telescope was one of the first to capture clear images of the bulk of the Shapley concentration, revealing the enormous density of galaxies in this distant region of space.

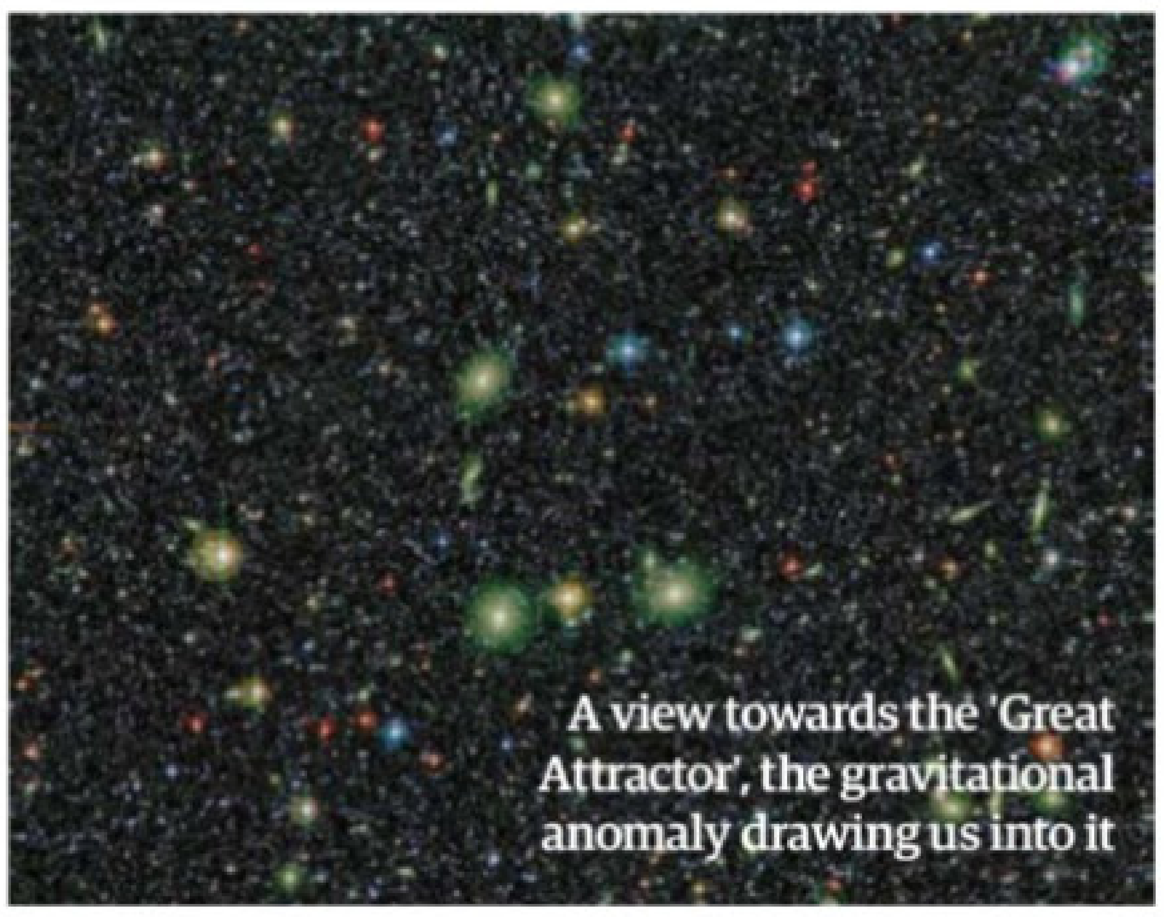
The Shapley supercluster lies in a part of the sky known as the Zone of Avoidance, a region almost entirely obscured by the dust, gas and stars that make up the centre of the Milky Way. This makes it challenging to image, but by using X-ray equipment astronomers are able to peer through the haze.

The Clusters in the Zone of Avoidance (CIZA) project aimed to map the galaxies in this obscured area of the sky, hoping to reveal the identity of the Great Attractor. However, when they looked at the Hydra-Centaurus supercluster, it was much less massive than had been predicted. The Norma cluster, once thought to be the source of the Great Attractor's pull, contained just a tenth of the anticipated mass. However, far behind this cluster of galaxies, the full extent of the Shapley concentration started to become clearer and attentions turned to this enormous supercluster as the potential source of at least part of the attractive force detected.

The hot gas that shrouds the galaxy cluster structures like Shapley contains high-energy electrons that distort the microwave background, showing up as hot spots. In 2013, ESA's Planck space observatory released the most detailed image ever created of the cosmic microwave background radiation. In this all-sky map showing the last remnants of the Big Bang, the enormous Shapley concentration distorts the signal. The outline of its dense core can also clearly be seen – this is known as the Sunyaev-Zel'dovich effect.

It's possible that the Shapley supercluster extends further into space than we can currently resolve, and that there may even be a much larger structure behind it. NASA's James Webb Space Telescope, due to launch in 2018 in collaboration with the ESA and the CSA, will be equipped with extremely sensitive infrared equipment, so will be able to look farther than ever before in the direction of the Great Attractor and the Shapley concentration. One of its core objectives is to study the assembly of galaxies and the information that it will reveal about the structure of superclusters like Shapley will be invaluable in advancing our understanding of the structure of the universe. ■

Observing closer superclusters, like the Coma cluster, can reveal clues about how the Shapley supercluster evolved


A view towards the 'Great Attractor', the gravitational anomaly drawing us into it

The Cartwheel galaxy lies 500 million miles away and was first spotted by the UK Schmidt telescope

UK Schmidt telescope

Schmidt telescopes were developed in 1930 by Bernhard Schmidt and are designed around a spherical primary mirror. These kinds of mirrors are very easy to make, and offer a wide field of view, but they suffer from spherical aberration. This means, in order to properly focus the light onto a photographic plate, Schmidt added a correcting lens to bend its path as it entered the telescope.

The UK Schmidt telescope is located at the Siding Spring Observatory in Australia and was previously used purely for optical survey data – including the survey that picked up the Shapley supercluster in 1989. Recently the device has been fitted with a fibre-optic instrument, taking advantage of its advanced optics to perform detailed surveys of galaxy redshift.

Corrector lens
Light enters the telescope through a 1.2-metre (3.9-foot) corrector lens, which bends the light, correcting for the shape of the mirror and enabling the light to be properly focused.

Wide field
The UK Schmidt telescope takes images of a six-degree by six-degree slice of sky, providing a wide-field view.

Main mirror
The main mirror is concave and measures 1.8 metres (5.9 feet) in diameter. Concave mirrors suffer from spherical aberration – they don't naturally reflect all of the light back onto a single point.

Plate holder
The original photographic plates have now been replaced by fibre-optic spectrograph equipment, used to rapidly measure galaxy redshift.

Camera only
The UK Schmidt telescope is a camera and does not enable an observer to look directly at the sky. Instead, the images are caught as individual photograph stills.

© Getty Images; NASA; Sayo Studio; Adam Evans; Hewholooks; Andrew Z Colvin; 2MASS; ESA; JPL-Caltech/UCLA; Bill Schoening, Vanessa Harvey/REU program/NOAO/AURA/NSF; Hubble; Scott Anttila/Anttler;

What is the Torino Scale?

This scale measures the overall threat to Earth of impact from asteroids and other near-Earth objects

Calculating whether an asteroid, comet or other object is going to hit Earth from outer space is more complicated than you might think. It isn't just a matter of detecting the object and its velocity through space, working its trajectory out, then putting the two together and seeing if this sets it on a collision course with Earth. Astronomers will ask a number of questions like: if we think it will collide, when is its estimated date of collision? How much deviation is there in our calculations? Is it possible that, in the time between now and the estimated impact date, something will happen to send it off our calculated course?

Global space agencies like to add other factors to the equation, like the mass of the asteroid and how long it's going to take to reach Earth. If a relatively tiny asteroid with a mass of ten kilograms (22 pounds) is going to hit Earth within the next hour, the governments of the world are hardly going to run to their bunkers. Similarly, if a ten-kilometre- (6.2-mile-) wide, Chicxulub-mass comet is likely to impact Earth 500 years from now and cause a catastrophe of global proportions, no-one's going to sweat that much (for now), either.

The Torino Scale is an accessible, visual version of more-scientific impact hazard scales. It distills data from objects in space down to a zero-to-ten scale of their threat to Earth, then grades that scale into five distinct bands. A zero (blue) rating indicates an object that has no chance of hitting Earth or is so small its impact will be hardly noticed. By contrast, an object with a rating of eight, nine or ten (red) is not only certain to hit the Earth, it has a high chance of widespread devastation and may even cause catastrophic global environmental changes.

The first draft of the scale was created by the Massachusetts Institute of Technology's professor of planetary sciences, Richard Binzel, in 1995. At the time, it was called a 'Near-Earth Object Hazard Index'. Its name changed to the Torino Impact Hazard Scale in 1999 after the scale was revised at a conference on near-Earth objects in Turin, Italy (Torino in Italian). After a bout of sensational press coverage over big asteroids with a very low probability of hitting Earth, its categories were renamed and their details revised again, resulting in the Torino Scale that we have today.

Although the scale rates up to a threat level of ten, objects of that apocalyptic nature come along once in every 100,000 years or more. And a level eight – a certain impact capable of flattening many square miles – might come along once every millennium or so. In actual fact, scientists don't bother doing anything until level three, when other astronomers are alerted to the potential risk. We only really need to start to be concerned when a near-Earth object is graded level five or higher.

So what's the highest grading we've given so far, out of all the thousands of asteroid and comets rated since the Torino Scale was invented? That record goes to 99942 Apophis, a worryingly large asteroid 325 metres (1,066 feet) in diameter capable of widespread destruction... if it were to hit Earth. It briefly scored a four on the Torino scale in 2004, before being downgraded to a one after further calculation. Apophis is a near-Earth object with an orbital path that frequently takes it close to Earth but, all the same, scientists put the odds of a near-future impact with this asteroid in the millions, if not billions to one. Of course, this low probability effectively makes it a zero on the Torino Scale. ■

Threat level

🟥 **Certain collisions** 08 09 10
Impactors in this bracket aren't just guaranteed to hit Earth, they can be game-changers for life as we know it.

🟧 **Serious threat** 05 06 07
Probability of a major impact is high but uncertain. International contingency plans may be required.

🟨 **Merits attention** 02 03 04
At this level, there may be a close encounter with a reasonably large object. Astronomers will be notified.

🟩 **Normal** 01
A routine discovery of a pass near Earth with a negligible chance of impact. Will likely downgrade to 0.

🟦 **No hazard** 0
Zero chance of collision, or an object so small that it either burns up in the atmosphere or causes no damage.

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07
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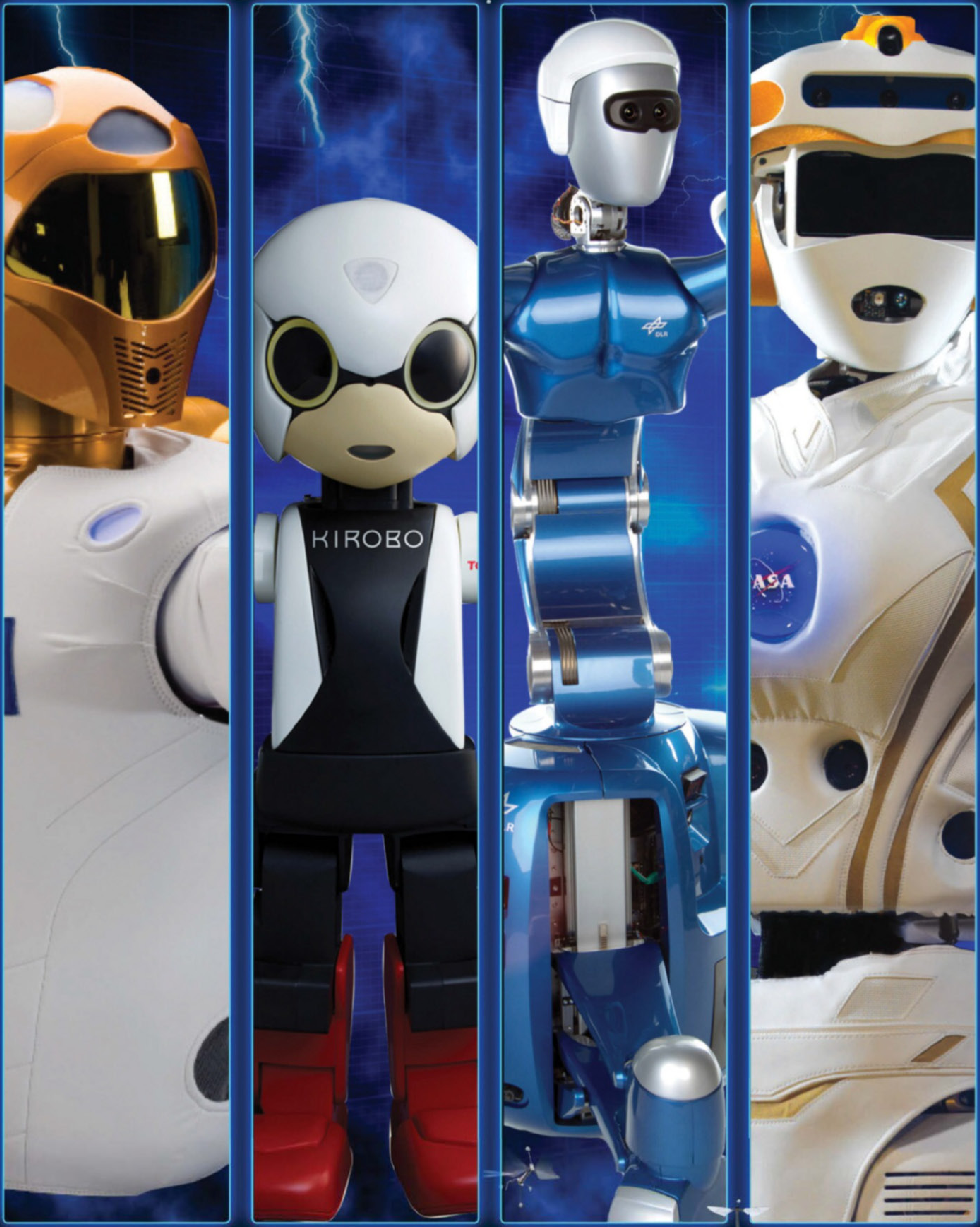
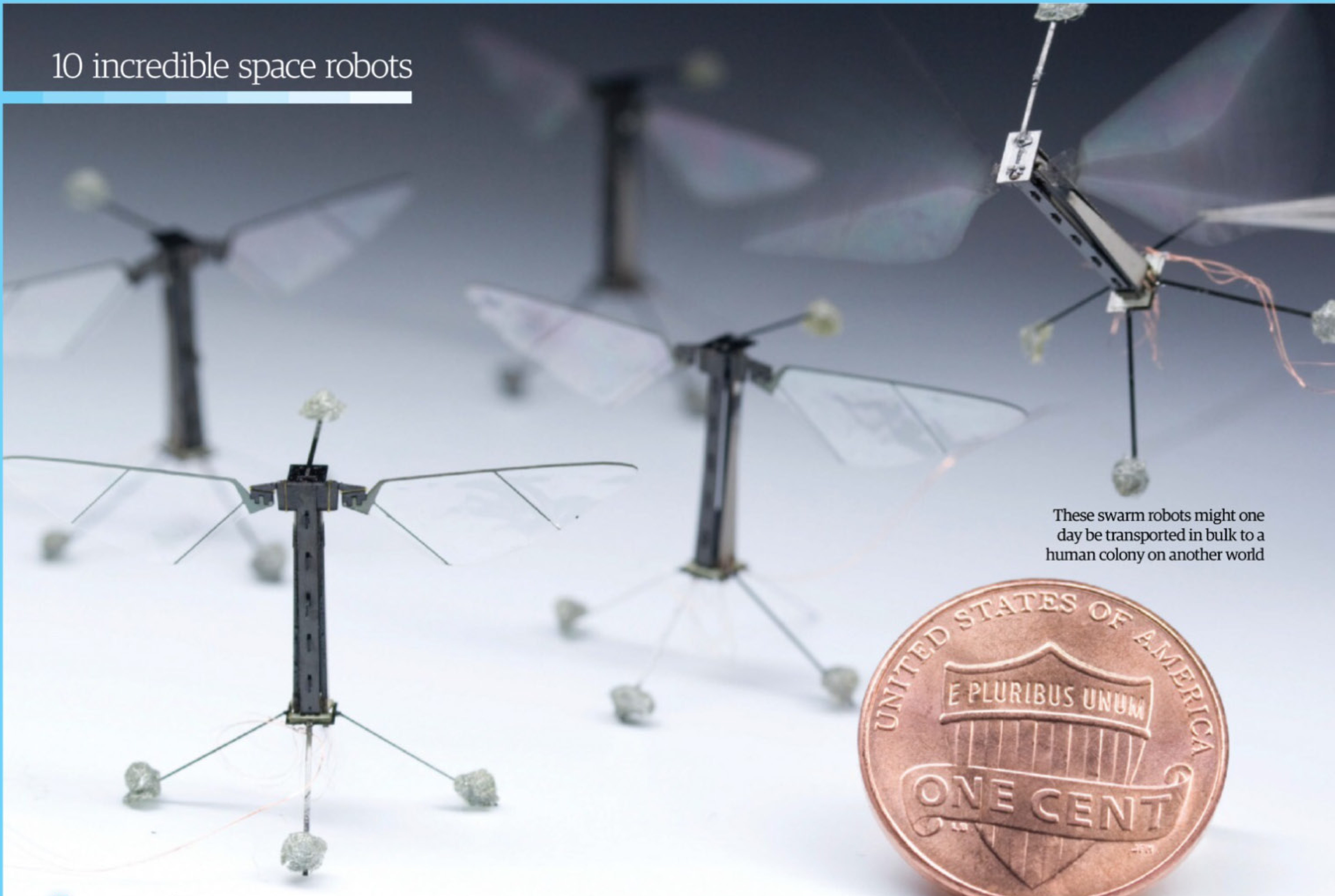
Probability of impact


KIROBO
DLR
NASA

10 INCREDIBLE SPACE ROBOTS

From flying android space bees to an autonomous submarine on another world, we unveil the robots that could change space exploration forever

Written by Jonathan O'Callaghan



These swarm robots might one day be transported in bulk to a human colony on another world

1 RoboBees

These tiny androids could pollinate plants on an extraterrestrial colony

If we are to one day colonise distant worlds such as Mars, the current line of thinking is that we will need to grow plants to create a sustainable colony.

On Earth plants are pollinated by bees, but on a world where such life doesn't exist, the problem is just how plants will spread their pollen and in turn produce fruit and seeds?

Perhaps this role will fall not to living organisms, but to tiny androids. It could be that future space explorers need look no further than RoboBees, developed by Harvard's School of Engineering and Applied Sciences. These tiny robots would be able to pollinate an extraterrestrial field of crops without input from humans, taking away the laborious process of manual pollination.

> "These tiny robots would be able to pollinate an extraterrestrial field"

Here on Earth researchers have proven that the RoboBees, which are nearly identical in size to regular bees, are able to fly successfully. The tiny wings use artificial muscles in the form of piezoelectric materials to move the wings. This means they could then transport pollen from plants. Each RoboBee weighs a miniscule 0.5 grams (0.02 ounces) meaning hundreds or even thousands could be taken on a future mission into space without taking up too much room.

While the Harvard scientists haven't announced plans to begin developing the RoboBees for use in space yet, others can already see the potential of such swarm robotics.

Researchers have published a paper on the challenges and applications of swarm robotics, in the International Journal of Engineering and Computer Science. It ponders the future of human civilisation and whether miniature robots will be used in colonies to build a suitable habitat for agriculture.

Key moments in space robot history

1981

Robotic arm
Canada develops a robotic arm for NASA for use on the Space Shuttle. A similar design is later used on the ISS.

1997

Robonaut 1
NASA begins work on Robonaut 1, initially intended to attach to the end of the robotic arm on the ISS and assist astronauts.

2001

Canadarm2
Also known as the Mobile Servicing System (MSS), Canadarm2 has assisted with spacewalks ever since 2001.

2006

SPHERES
The bowling ball-sized autonomous SPHERES were first launched to the ISS in 2006 to test rendezvous and docking techniques.

2 Android pioneer

The humanoid robot that could beat humans to Mars

Who will take the first step on Mars: man or machine? If this NASA robot gets its way, the first giant leap on the Red Planet will be for humanoid robot-kind.

Valkyrie is a robot intended to one day work on another world as a precursor to human explorers. The prototype is roughly the same height as a human but weighs a rather hefty 130 kilograms (287 pounds). A suite of cameras enables it to walk upright and hold tools, while a backpack means it can wander around and stay powered without needing to remain plugged into a power source.

By using a human-like design, the team behind the robot says it would be capable of traversing difficult terrain, such as on Mars, and could examine samples like rocks with ease.

It has 44 degrees of freedom, helping it mimic the actions of a human as closely as possible, while its hands can move, spin and grasp. Perhaps its best feature of all is that it can replace its limbs, swapping any dodgy arms out in a matter of minutes.

Admittedly the robot still has a long way to go to be considered as a viable future space explorer. It's in the very early stages and will need to ultimately be autonomous, much lighter and also much more capable. However, the potential for robots like these to explore dangerous locations where humans cannot tread just yet is plain to see.

Valkyrie is a next-generation humanoid robot that one day might be used as a precursor to humans to walk on another world

NASA's SPHERES have been on the ISS since 2006

3 Flying training bots

Star Wars-inspired robots that will test spacecraft tasks on the ISS

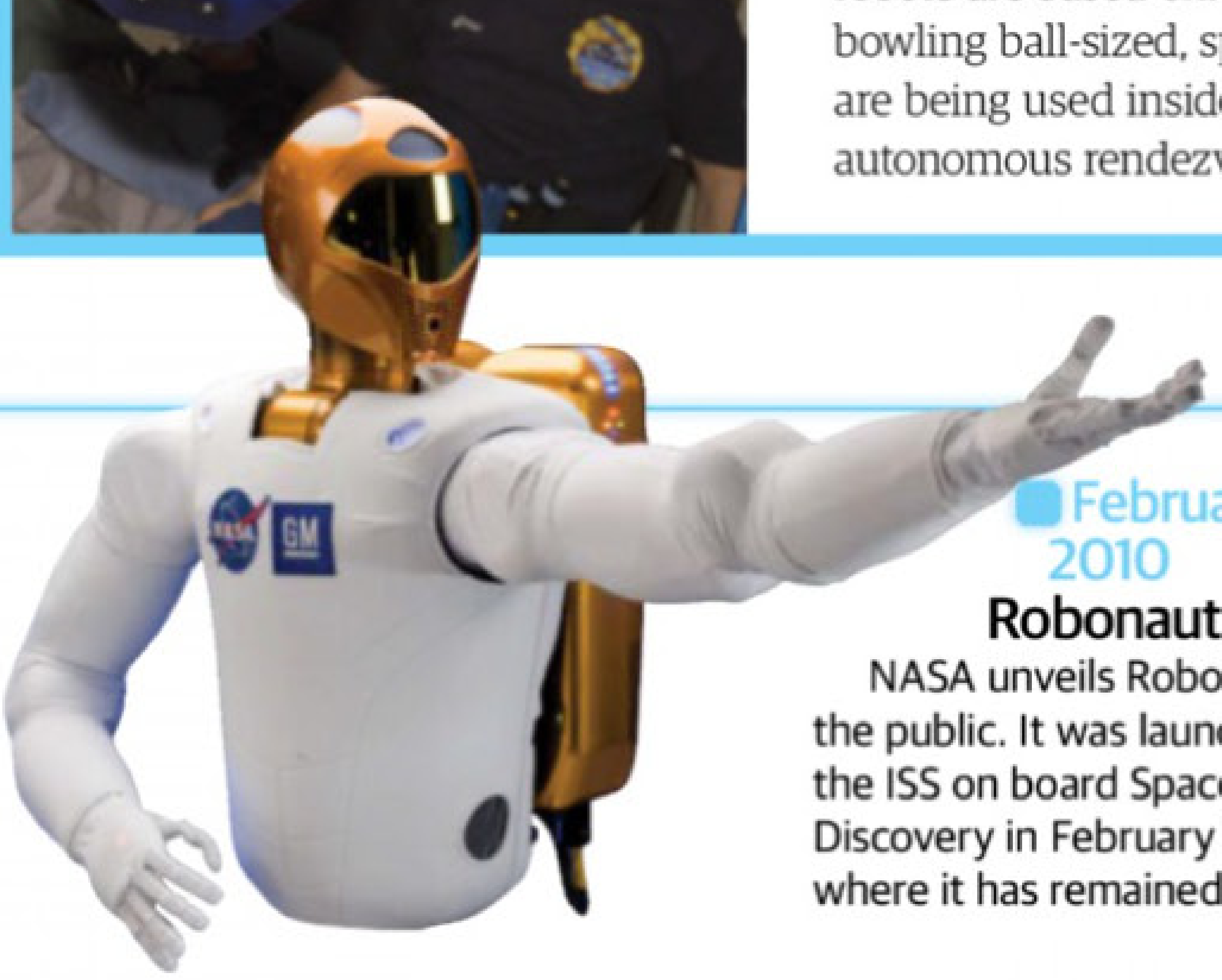
Star Wars fans may remember in *Episode IV: A New Hope*, when Luke Skywalker is training to become a Jedi by protecting himself with a lightsaber from floating balls that fire lasers.

Well, that's exactly what these robots are based on. Three of these bowling ball-sized, spherical satellites are being used inside the ISS to test autonomous rendezvous and docking manoeuvres for spacecraft. Inside the ISS the SPHERES can fly freely, attempt obstacle-avoidance, meet up with one another and more.

Each robot has its own power, propulsion, computers and navigation equipment. They measure around 25 centimetres (9.8 inches) in diameter and use 12 carbon dioxide thrusters to fly around the cabin.

NASA is planning to upgrade each of them with a smartphone loaded with Google's new 3D-mapping software, Project Tango. Using this they will be able to operate in the ISS faster than their 2.5-centimetre- (one-inch-) per-second top speed.

It's hoped the robots could perform routine tasks outside the ISS to save astronauts from making spacewalks.



February 2010

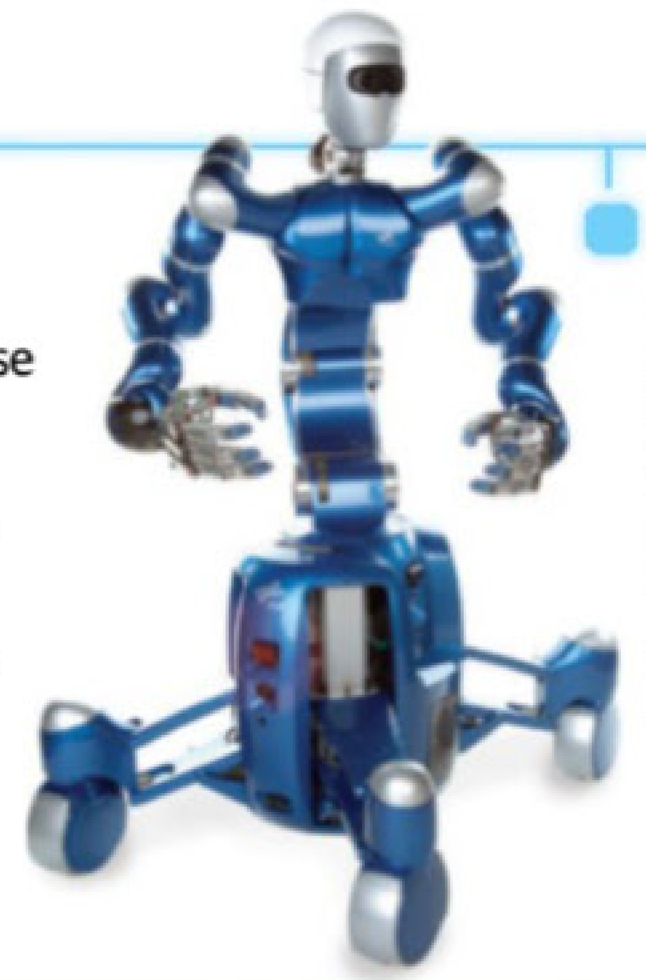
Robonaut 2

NASA unveils Robonaut 2 to the public. It was launched to the ISS on board Space Shuttle Discovery in February 2011, where it has remained since.

August 2013

Kirobo

The talking Japanese robot Kirobo was delivered to the ISS in August 2013 to test how well it could interact with the astronauts.



Late 2014

Rollin' Justin

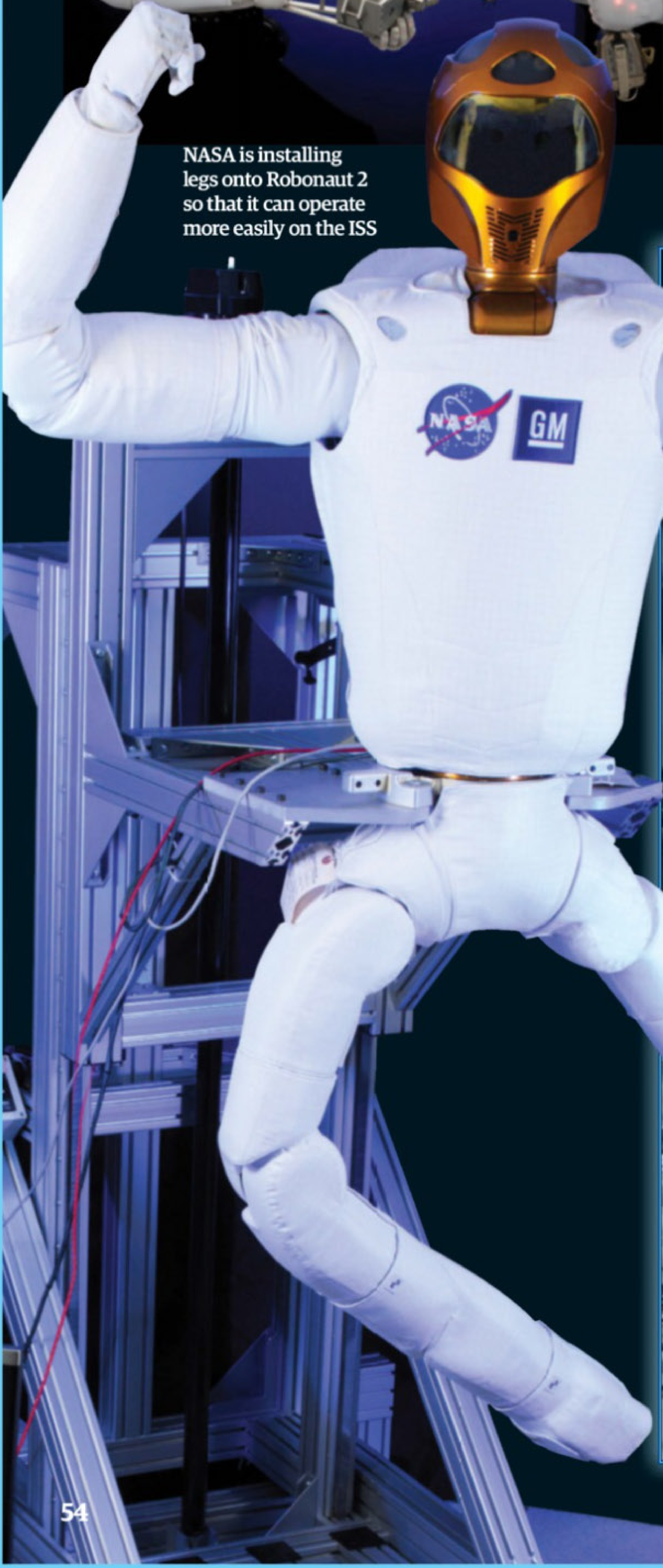
Later in 2014 ESA is planning to task astronauts on the ISS with teleoperating a wheeled Justin robot on Earth.

4 Robonaut 2

The star-studded celebrity of space robots

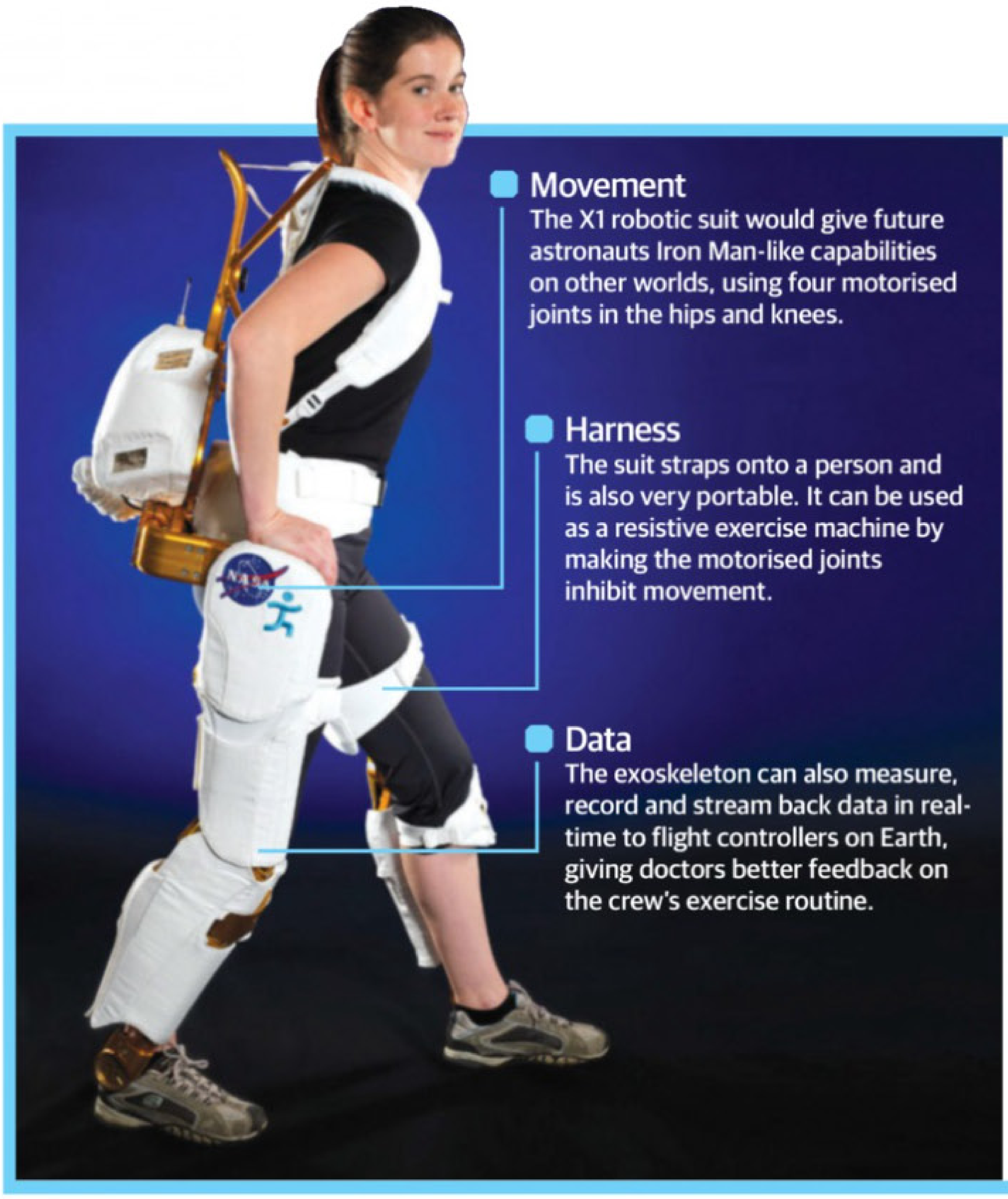
One of the most-famous space robots of all is undoubtedly NASA's Robonaut 2. This humanoid robot is currently resident on the ISS and the ultimate goal is for it to work with astronauts not only inside the space station, but also outside on spacewalks as well. For now, however, the robot is limited to operations inside the ISS as it lacks adequate protection to work in the cold vacuum of space. It has been designed with a huge level of dexterity. Over 350 sensors provide details of its surroundings, while its arms can move up to two metres (seven feet) per second. At the moment the robot is operated through telepresence (either a ground controller or ISS crew member controls it), but eventually it will be a totally autonomous machine.

Earlier this year, NASA sent up a pair of legs that astronauts on the ISS will attach to Robonaut 2. These extra limbs will enable it to attach to hand rails and harnesses in the ISS, just like astronauts do in order to stay secure when working with station machinery.



NASA is installing legs onto Robonaut 2 so that it can operate more easily on the ISS

Starting with just a torso, arms and a head, Robonaut 2 now features a set of legs



Movement
The X1 robotic suit would give future astronauts Iron Man-like capabilities on other worlds, using four motorised joints in the hips and knees.

Harness
The suit straps onto a person and is also very portable. It can be used as a resistive exercise machine by making the motorised joints inhibit movement.

Data
The exoskeleton can also measure, record and stream back data in real-time to flight controllers on Earth, giving doctors better feedback on the crew's exercise routine.

5 X1 Exoskeleton

NASA's plan to send Iron Man to Mars

Today on the ISS astronauts exercise using a number of machines that resist their movement or by running on a treadmill of sorts. NASA's X1 robotic exoskeleton, however, will be a new exercise machine that can work in direct contrast to the superhero Iron Man.

Where Tony Stark's suit gives him superhuman strength and movement, the X1 will be used to help astronauts stay healthy in space by providing a resistive suit they can move against.

It has four motorised joints at the hips and knees and six passive joints for sidestepping, turning and pointing feet. One of the major advantages of this system - inspired by Robonaut 2 - over existing space exercise machines is that it is much smaller. This means that, perhaps on future missions to Mars, it could provide astronauts in confined spaces with a portable exercise machine.

Its motion-inhibiting features can also be reversed. This could give an astronaut on the surface of Mars, for example, the superhuman strength afforded to Iron Man. Some day the same technology may be applied to help paraplegics on Earth walk again.

6 The wall-climber inspired by nature

Will this space gecko one day clamber around satellites?

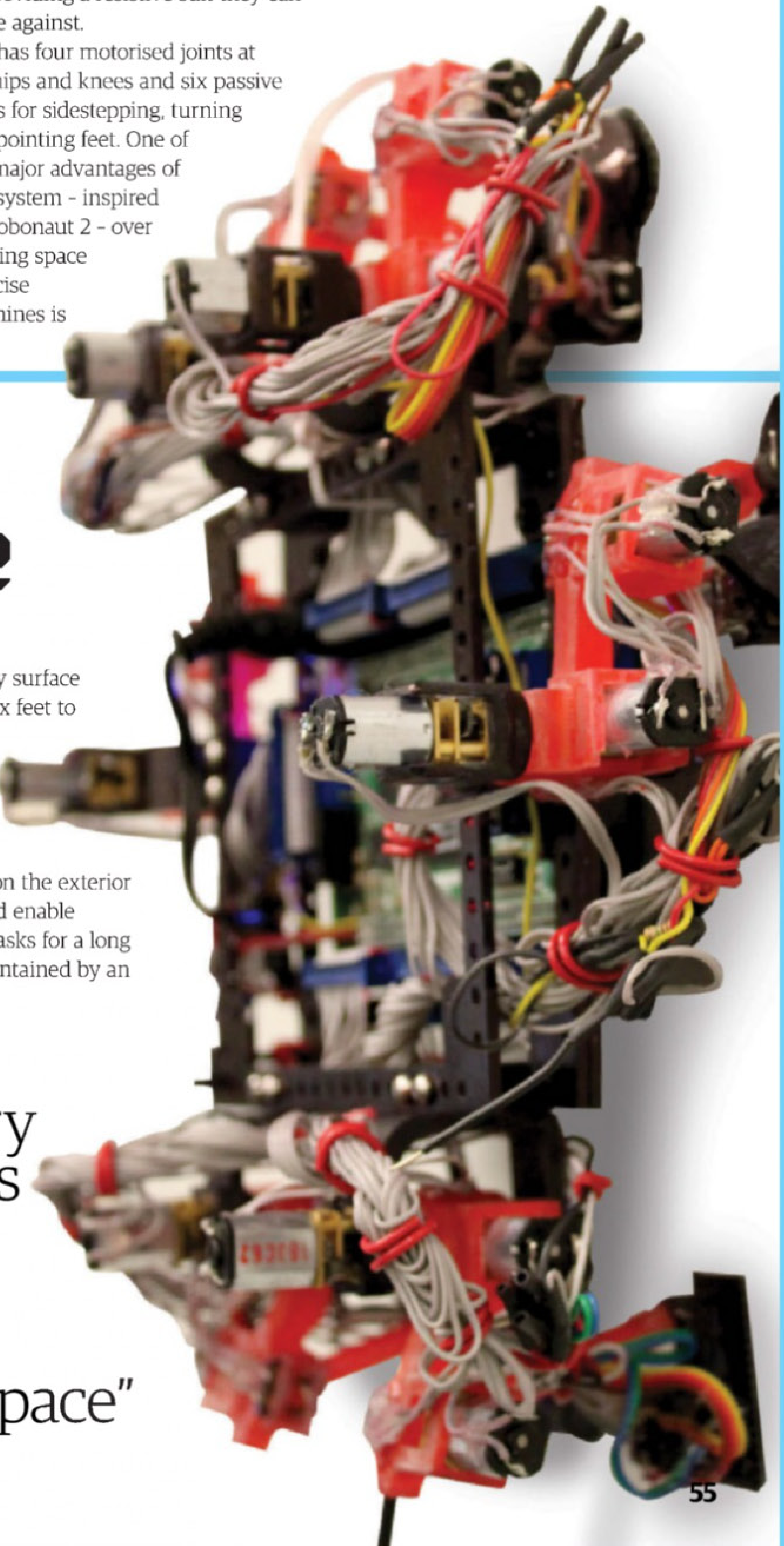
When thinking of the optimum design for a space-bound robot, a gecko probably isn't the first thing that comes to mind. But that's exactly what ESA is working on with Abigaille, a robot that mimics the stickiness of the lizard's feet to work in space. Researchers found the dry adhesiveness of a gecko's foot worked even in the vacuum of space, leading them to design the small robot.

Abigaille has tiny hairs on its feet measuring about 100 to 200 nanometres across (for comparison a human hair is 100,000 nanometres in diameter) that stick to surfaces. At this scale the hairs even manage to induce atomic interactions with any surface they meet. This enables each of the six feet to stick and restick to surfaces with no debilitating effects that come with using other implements such as tape or magnets.

It's hoped that the small vehicle might be used in the future to crawl on the exterior of satellites and spacecraft. This would enable Abigaille to perform repairs or other tasks for a long time, without even needing to be maintained by an astronaut operator.

Tiny hairs on the feet of Abigaille enable it to clamber up walls

"Researchers found the dry adhesiveness of a gecko's foot worked even in the vacuum of space"



Kirobo has a twin called Mirata that has the same characteristics. Mirata stays on Earth as backup crew

7 Kirobo

This talking robot could keep lonely astronauts company

Imagine a future where just a single human astronaut travels on a mission to Mars, but they're not alone – with them is a robot that can talk and act like a person, keeping the solitary human company as they work.

That's a future the University of Tokyo, with its Kirobo android, is working towards. The small robotic companion arrived at the ISS on 9 August 2013 and, with the arrival of JAXA astronaut Koichi Wakata on 7 November, scientists tested out its conversation abilities.

The robot, weighing just one kilogram (2.2 pounds), has capabilities that include voice and speech recognition and even the ability to recognise faces.

'How did you get out here into space, Kirobo?' asked Wakata in Japanese during a trial, which is the only language the robot speaks. 'On Kounotori from Tanegashima,' the robot replied. This refers to the vehicle that took the robot to the station, Kounotori 4, as well as the launch site, Tanegashima Space Centre in Japan.

While it's a primitive conversation for now, through continued research scientists hope to one day design talking robots that can keep astronauts company on missions.

8 Remote-control robot mechanic

This German android will one day be used to repair satellites

To test out exciting new developments in remote-control technology, the German Aerospace Centre (DLR) is developing Justin for ESA, an android that will soon be controlled from afar by astronauts on the ISS. Justin has four wheels, two arms, weighs about 200 kilograms (440 pounds) and is about as tall as a regular human.

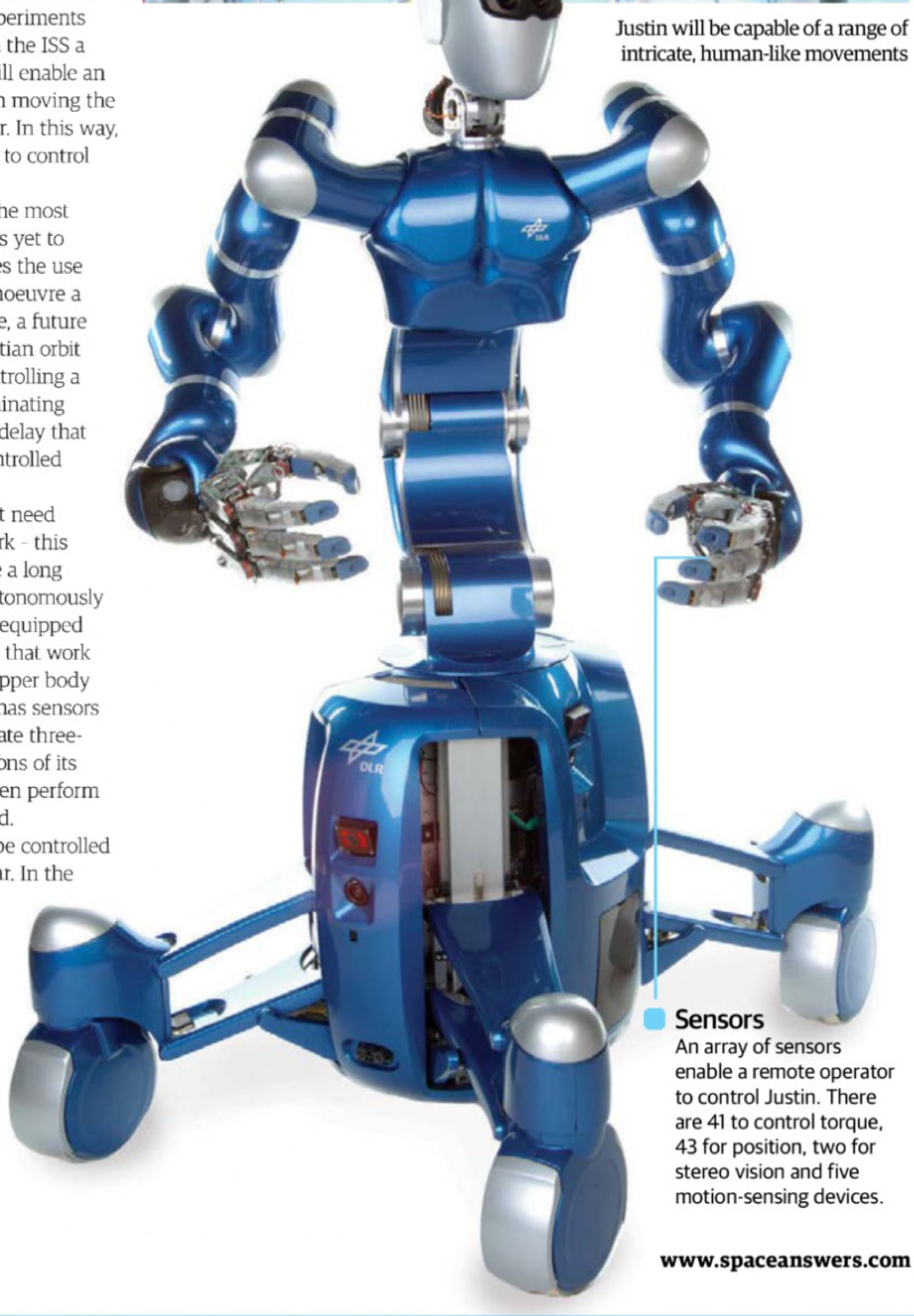
It's a humanoid robot with lightweight, articulated arms and two hands with four fingers. This makes it ideal for conducting experiments in inhospitable places. On the ISS a remote-motion system will enable an astronaut to move, in turn moving the robot in the same manner. In this way, the astronaut will be able to control the robot on the ground.

Telerobotics is one of the most exciting realms of robotics yet to be truly tapped. It involves the use of remote controls to manoeuvre a distant robot. For example, a future astronaut working in Martian orbit might be tasked with controlling a robot on the surface, eliminating the 16-minute or so time delay that would result if it were controlled from back here on Earth.

However, Justin doesn't need a human astronaut to work – this mobile platform will have a long range and can operate autonomously if necessary. The robot is equipped with independent wheels that work in equilibrium with the upper body to provide a firm base. It has sensors and cameras that can create three-dimensional reconstructions of its environment, so it can even perform without human command.

Justin is scheduled to be controlled from the ISS later this year. In the future there are plans to have a free-floating version in space that astronauts can use to fix satellites, while much further down the line, telerobots like Justin will enable us to explore worlds such as the Moon and Mars from orbit.

Justin will be capable of a range of intricate, human-like movements



Sensors
An array of sensors enable a remote operator to control Justin. There are 41 to control torque, 43 for position, two for stereo vision and five motion-sensing devices.

9 Titan Aerial Daughtercraft

The autonomous robot that might one day explore the skies of Saturn's moon

Titan is arguably the most-desirable place in the Solar System that space scientists want to visit, as it's the most Earth-like world within our reach. With liquid lakes on its surface, a climate system and even a thick atmosphere, experts the world over have been clamouring for a mission to Saturn's giant moon to advance upon the pioneering but brief visit the Huygens probe made to its surface in 2005.

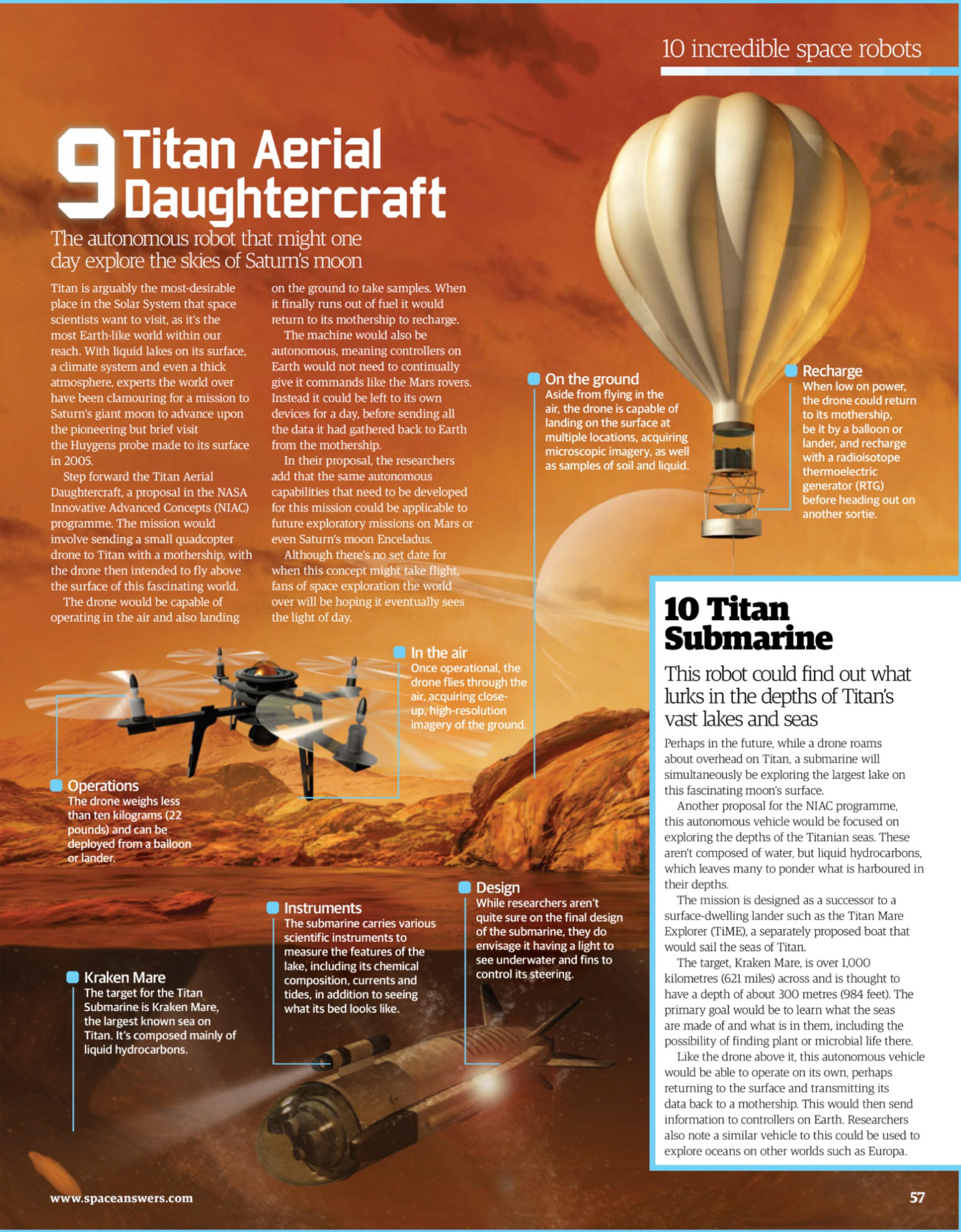
Step forward the Titan Aerial Daughtercraft, a proposal in the NASA Innovative Advanced Concepts (NIAC) programme. The mission would involve sending a small quadcopter drone to Titan with a mothership, with the drone then intended to fly above the surface of this fascinating world.

The drone would be capable of operating in the air and also landing on the ground to take samples. When it finally runs out of fuel it would return to its mothership to recharge.

The machine would also be autonomous, meaning controllers on Earth would not need to continually give it commands like the Mars rovers. Instead it could be left to its own devices for a day, before sending all the data it had gathered back to Earth from the mothership.

In their proposal, the researchers add that the same autonomous capabilities that need to be developed for this mission could be applicable to future exploratory missions on Mars or even Saturn's moon Enceladus.

Although there's no set date for when this concept might take flight, fans of space exploration the world over will be hoping it eventually sees the light of day.



On the ground
Aside from flying in the air, the drone is capable of landing on the surface at multiple locations, acquiring microscopic imagery, as well as samples of soil and liquid.

Recharge
When low on power, the drone could return to its mothership, be it by a balloon or lander, and recharge with a radioisotope thermoelectric generator (RTG) before heading out on another sortie.

In the air
Once operational, the drone flies through the air, acquiring close-up, high-resolution imagery of the ground.

Operations
The drone weighs less than ten kilograms (22 pounds) and can be deployed from a balloon or lander.

Kraken Mare
The target for the Titan Submarine is Kraken Mare, the largest known sea on Titan. It's composed mainly of liquid hydrocarbons.

Instruments
The submarine carries various scientific instruments to measure the features of the lake, including its chemical composition, currents and tides, in addition to seeing what its bed looks like.

Design
While researchers aren't quite sure on the final design of the submarine, they do envisage it having a light to see underwater and fins to control its steering.

10 Titan Submarine

This robot could find out what lurks in the depths of Titan's vast lakes and seas

Perhaps in the future, while a drone roams about overhead on Titan, a submarine will simultaneously be exploring the largest lake on this fascinating moon's surface.

Another proposal for the NIAC programme, this autonomous vehicle would be focused on exploring the depths of the Titanian seas. These aren't composed of water, but liquid hydrocarbons, which leaves many to ponder what is harboured in their depths.

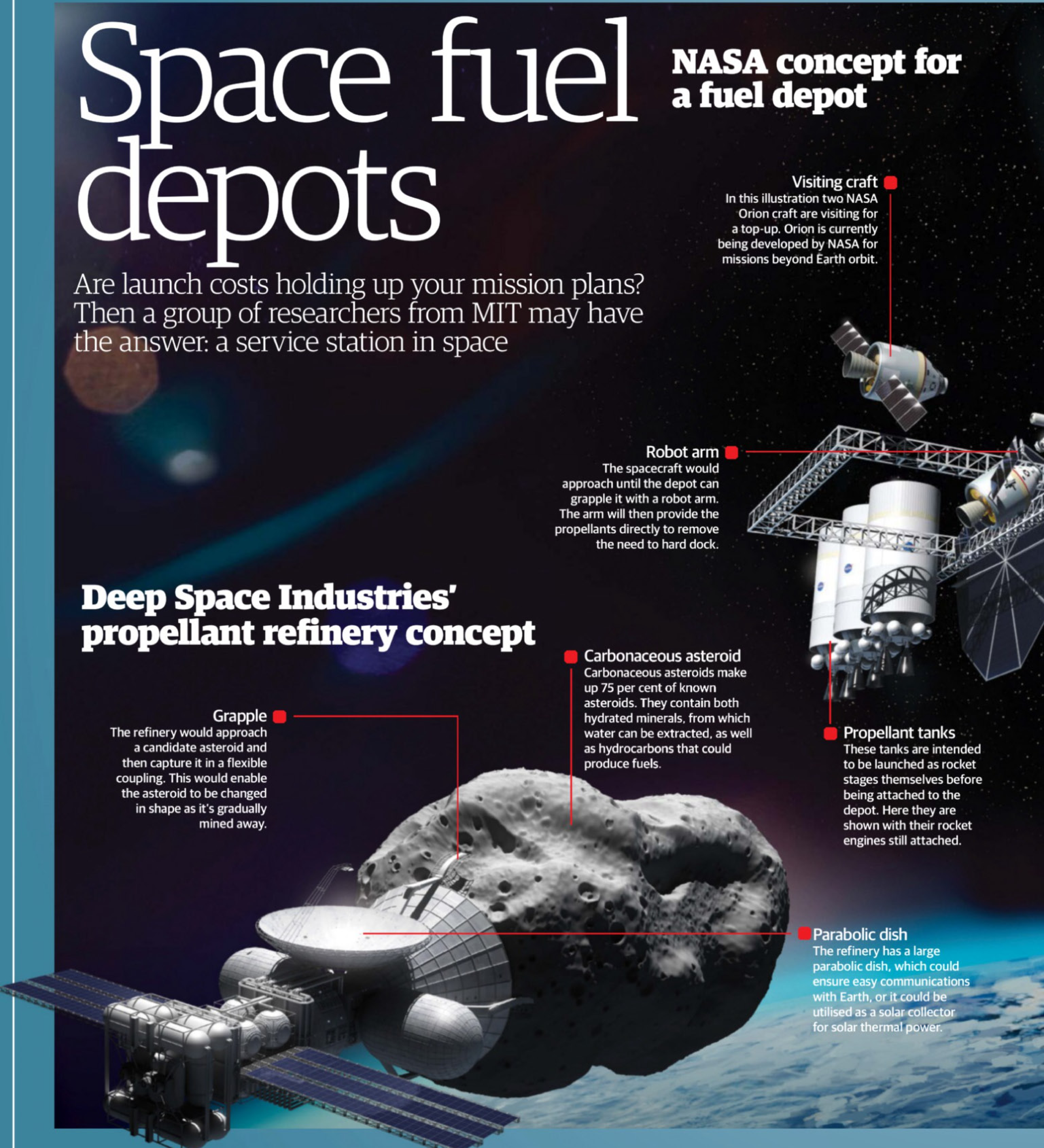
The mission is designed as a successor to a surface-dwelling lander such as the Titan Mare Explorer (TiME), a separately proposed boat that would sail the seas of Titan.

The target, Kraken Mare, is over 1,000 kilometres (621 miles) across and is thought to have a depth of about 300 metres (984 feet). The primary goal would be to learn what the seas are made of and what is in them, including the possibility of finding plant or microbial life there.

Like the drone above it, this autonomous vehicle would be able to operate on its own, perhaps returning to the surface and transmitting its data back to a mothership. This would then send information to controllers on Earth. Researchers also note a similar vehicle to this could be used to explore oceans on other worlds such as Europa.

Space fuel depots

Are launch costs holding up your mission plans? Then a group of researchers from MIT may have the answer: a service station in space



NASA concept for a fuel depot

Visiting craft
In this illustration two NASA Orion craft are visiting for a top-up. Orion is currently being developed by NASA for missions beyond Earth orbit.

Robot arm
The spacecraft would approach until the depot can grapple it with a robot arm. The arm will then provide the propellants directly to remove the need to hard dock.

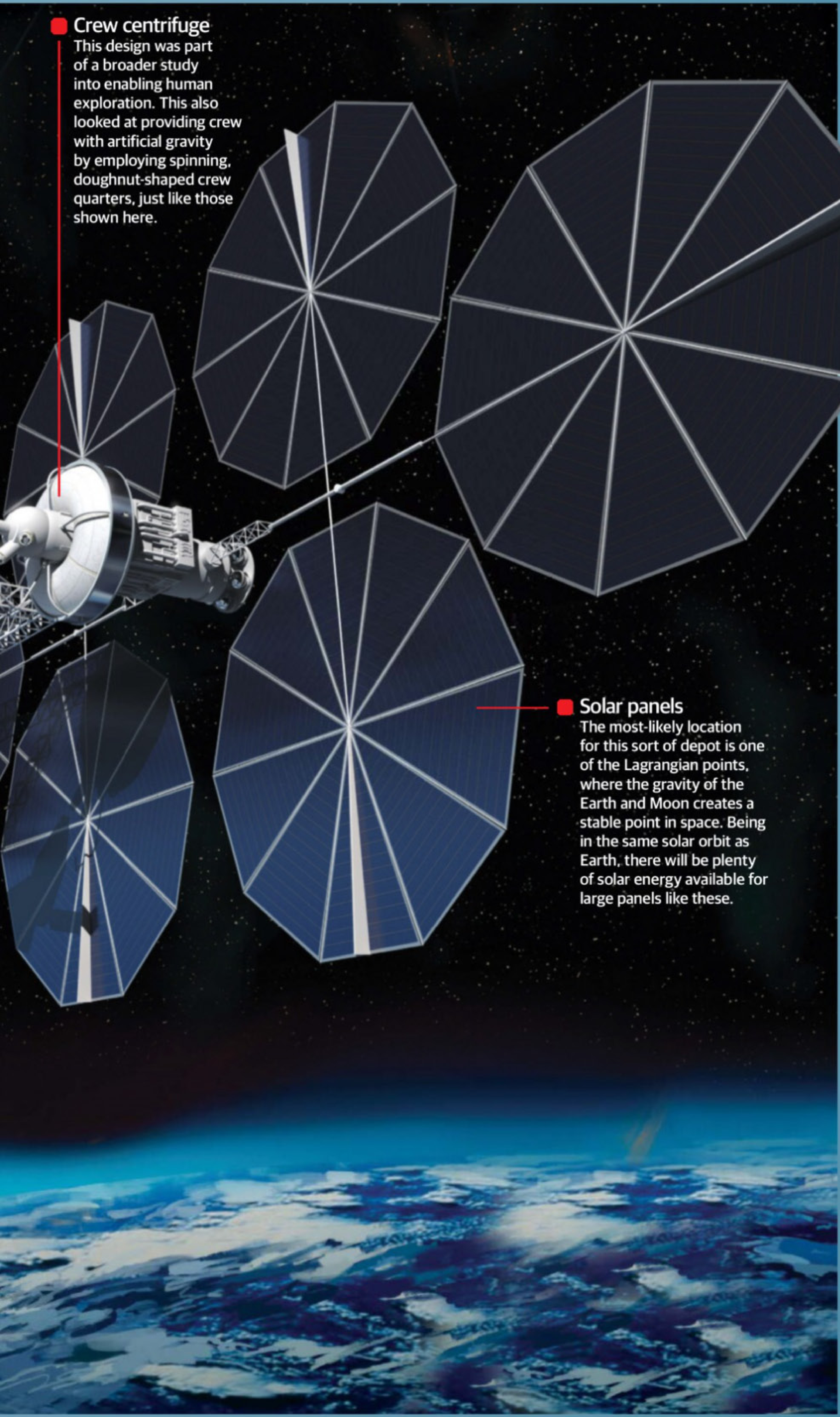
Propellant tanks
These tanks are intended to be launched as rocket stages themselves before being attached to the depot. Here they are shown with their rocket engines still attached.

Deep Space Industries' propellant refinery concept

Grapple
The refinery would approach a candidate asteroid and then capture it in a flexible coupling. This would enable the asteroid to be changed in shape as it's gradually mined away.

Carbonaceous asteroid
Carbonaceous asteroids make up 75 per cent of known asteroids. They contain both hydrated minerals, from which water can be extracted, as well as hydrocarbons that could produce fuels.

Parabolic dish
The refinery has a large parabolic dish, which could ensure easy communications with Earth, or it could be utilised as a solar collector for solar thermal power.



Crew centrifuge
This design was part of a broader study into enabling human exploration. This also looked at providing crew with artificial gravity by employing spinning, doughnut-shaped crew quarters, just like those shown here.

Solar panels
The most-likely location for this sort of depot is one of the Lagrangian points, where the gravity of the Earth and Moon creates a stable point in space. Being in the same solar orbit as Earth, there will be plenty of solar energy available for large panels like these.

Getting into space is hard. With the engines and rockets we have now, the majority of the weight of a rocket at launch is fuel and oxidiser to overcome Earth gravity. If we want to go beyond Earth orbit the problem gets even worse, so NASA is building the massive Space Launch System (SLS) rocket, to support its plans for visiting asteroids and Mars.

If you could fuel up your interplanetary mission in orbit, instead of having to launch everything in one go, the cost of individual missions could be cut significantly. With this in mind, a team from MIT has proposed an intermediate concept that could build up propellant depots with traditional missions.

Led by Professor Jeffrey Hoffman, himself a veteran of five Shuttle missions, the team propose to take advantage of contingency propellants that would be carried on lunar missions anyway. This is the surplus that must be there to cope with mission problems, if everything goes to plan then these unused reserves could be left in space to establish a depot. The depot could then be used in two ways. First, in a steady-state situation where each mission collects (and hopefully leaves behind) its contingency propellant. With the cost of sending anything beyond Earth orbit being so high, even this would be an important saving. Second, smaller missions (maybe even lunar flights) could keep launching with a contingency so that a stockpile accumulates at the depot. This means much more-ambitious missions (maybe to Mars or an asteroid) could be launched with minimal propellant and collect the stockpile.

As well as the mission planning, MIT has also looked at the practical side of collecting the resources. Pumping the propellants like filling up a car would be challenging, because they don't all sit nicely at one end of the tank. One suggestion has been to spin the tank, but then you would have to deal with the rotation of the depot too. MIT's concept is instead built around modular tanks that could be exchanged like a battery and plugged into the ship ready for use. These modules would remain available in space as part of the whole depot system.

The ideal would be to live off the land – after all, we may still be filling in the map of the Earth if explorers had been forced to take everything they would need with them! We want to get to the point where we only have to launch people and luggage, and source everything else in space. That could be where Deep Space Industries (DSI) comes in, and its first step is propellant depots.

DSI is working on a number of technologies to enable space mining, refining and manufacturing. After an initial reconnaissance phase to identify suitable asteroids and return samples, the company intends to start mining metallic materials and use its own special design of 3D printer to build hardware from them in space. Along with the mining, it plans to refine propellants and water from asteroids, returning to Earth orbit for sale. This would finally enable missions to launch completely empty and pick up all their heavy propellants in orbit. As science-fiction author Robert Heinlein said: "Once you're in Earth orbit you're halfway to anywhere in the Solar System." Soon you'll be able to stop halfway and top your tank up too.

© Adrian Mann; Jay Wong

LIFE in the SOLAR SYSTEM

Despite acid clouds, molten heat, deadly radiation and bitter cold, could we still be sharing our cosmic neighbourhood?

Written by Colin Stuart

On the north-eastern border of the vast Vatnajökull glacier, Iceland, lies the Kverkfjöll mountain range, where a string of active volcanoes pepper the bleak, Icelandic landscape. Deep under the mountains, searing-hot magma gathers in cavernous chambers. Heat escaping from the chambers warms the glacial ice overhead, sculpting it into a spectacular ice cave some 2.8 kilometres (1.7 miles) long. The melt water crafts lakes that would freeze were it not for the hydrothermal energy escaping from the seething molten rock below.

These hot, acidic lakes may not seem like the most hospitable of places, but bacteria have made a home here. Ian Crawford, professor of planetary science and astrobiology at Birbeck, University of London, studies these hardy organisms. "Part of my work is sampling the water from these boiling, acidic lakes," he says. "We want to get an insight into the adaptations that life has had to make in order to exist there." These bacteria are just one example of extremophiles – lifeforms that don't just survive, but actively thrive in conditions once thought incredibly hostile. Halophiles have an incredibly high tolerance to salt; xerophiles persist in some of the driest places on the planet; while alkaliphiles flourish in highly alkaline locations.

The fact that life has been found eking out an existence in remote, desolate places on Earth has raised hopes of finding life doing the same in some of the more-extreme environments elsewhere in our Solar System. Ian Crawford's investigations in Iceland are helping us hunt for potentially habitable environments on Mars, for example. "Being boiled by acidic water alters the surrounding rock in a way that you can spot," he says. It's thought that the interaction between volcanoes and ice would have been a very common feature in Mars's history too. Recent Mars rovers have been equipped with instruments to detect the alterations to rock that Crawford describes, enabling them to hunt down areas on the Martian surface that could once have been home to hydrothermal pools. "Mars probably isn't habitable now, but it may have been in the past," Crawford explains. Even finding evidence of long-extinct life on the Red Planet would be a remarkable achievement.

Mars is perhaps the planet that has captured human imagination more than any other. Thanks to an army of rovers, landers and orbiters, we certainly know more about the planet than its other neighbours that we share the Solar System with. In fact, we know more about some parts of Mars than we do about parts of our own planet – we even have a better map of the Martian surface than we do of the ocean floor here on Earth. During more than ten years orbiting around Mars, the European Space Agency (ESA) Mars Express mission has imaged more than 95 per cent of the surface.

A total of four Mars rovers – robots that are driven by remote control from Earth – have been successfully deployed. Rovers Sojourner and Spirit have since been retired, while Opportunity and Curiosity are still active, with the latter recently celebrating its second anniversary of Mars exploration. Together they have revolutionised our understanding of the planet. As well as sending back glorious images, including spectacular Martian sunsets, they have scoured the surface looking for evidence that Mars was once habitable. What they have found so far is enticing.

It seems Mars used to be a warmer, wetter planet, with a much thicker atmosphere. Also, as much as a third of its surface was once covered with water. When Curiosity touched down in Gale Crater (which surrounds Mount Sharp on the Martian equator) and surveyed its new surroundings, its measurements suggested the landing site was once an expansive freshwater lake. When the rover drilled through local mudstones, it found minerals and nutrients that, coupled with the water, would have made the crater a distinctly habitable environment.

So the idea that Mars was once home to life billions of years ago is far from ridiculous. It is far more unlikely, however, that life persists on Mars today. The once wet planet is now an arid, dusty desert with only a thin atmosphere to protect any life from the many dangers of outer space. It seems the planet entered a climatic decline around 3.8 billion years ago. "Any life on the very surface would have died within a few million years, sterilised by cosmic radiation from the Sun and supernovae throughout the galaxy," says Dr. Lewis Dartnell, an astrobiologist at the University of Leicester. Dartnell's work has included taking extremophiles from the Dry Valleys of Antarctica - one of the most Mars-like places on Earth - and blasting them with radiation to see how they fare. Not well, seems to be the answer.

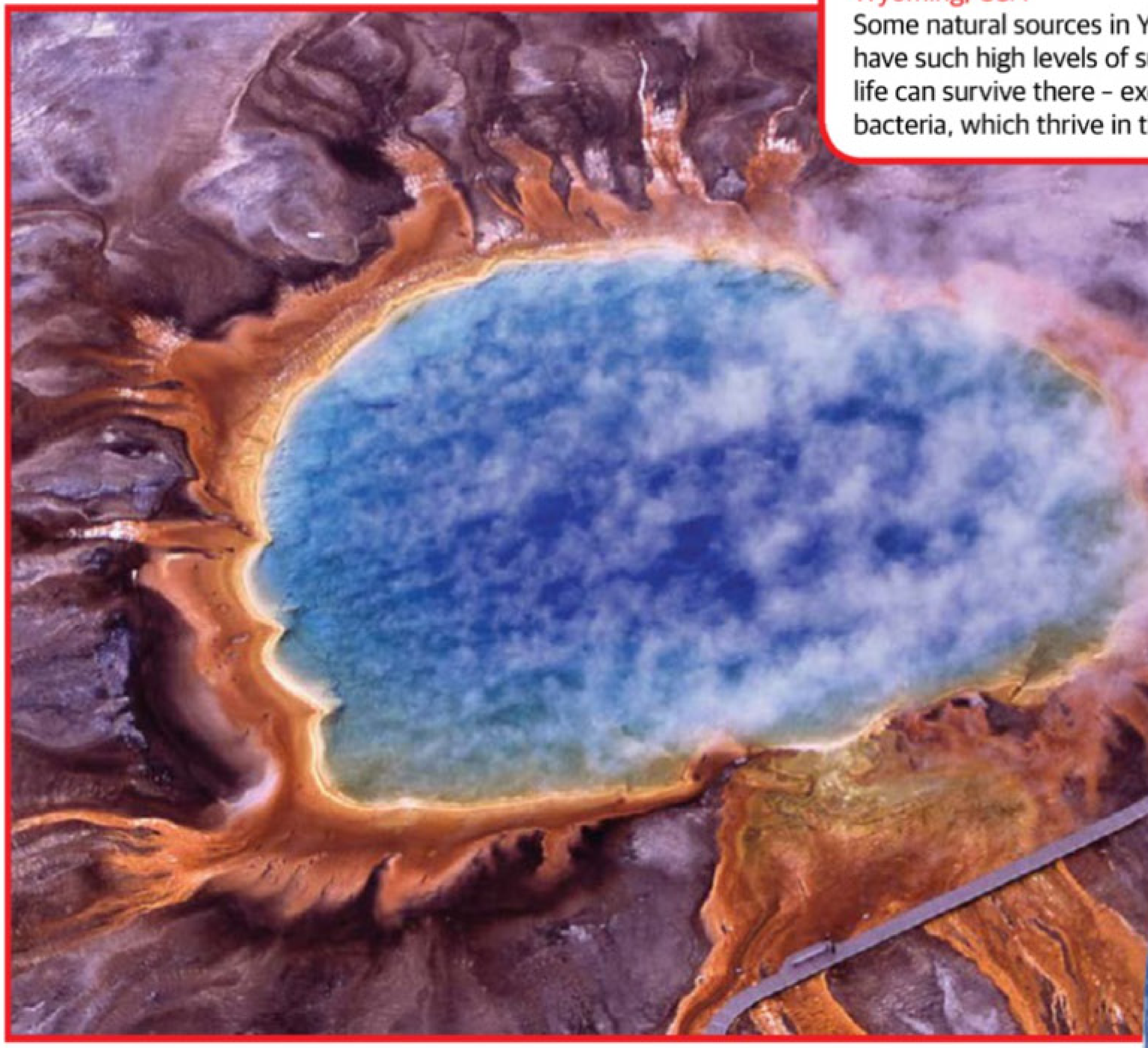
Contrary to popular belief, not one of the four successful Mars rovers has been equipped with instruments capable of detecting life - it's not what they were designed for. They've looked instead for evidence that the Red Planet had - or has - environments capable of supporting life. In other words, the right mix of water and nutrients, but not life itself. However, there have been two missions to Mars carrying the necessary tools to look directly for life: Viking 1 and 2 landers. The two NASA probes touched down on the Martian surface in 1976 and while they didn't move across the surface like the rovers, they were equipped with robotic arms capable of reaching out and scooping up samples of the Martian soil. These samples were then analysed for any signatures of life, but no such evidence was found by either probe.

This may be about to change, however. The first rover equipped with the right hardware to directly search for Martian life could be launched as early as 2018. ESA's ExoMars mission will have something that no previous rover has had: a sizeable drill. "ExoMars's drill will be two metres (6.6 feet) long - Curiosity's is only the length of your little finger," says Dartnell, who is working on the mission. Digging down under the Martian surface will enable scientists to probe a region where ancient life may have remained shielded from space radiation. ExoMars will also be armed with a panoramic camera - PanCam - that has been designed to look for similar changes in rocks to those seen by Ian Crawford in Iceland. It will be capable of looking for evidence that living organisms - past or present - have altered the texture of Martian rocks.

The answer to whether life ever got started on Mars, or perhaps is still there, may one day come from intricate and innovative missions. However, Mars isn't the only place in the Solar System that might be home to extraterrestrial lifeforms. It's possible that living organisms have made a home high in the clouds of our nearest planetary neighbour: Venus.

Venus, which is 95 per cent of the size of Earth and almost 1.5 times closer than us to the Sun, is hardly the poster child for habitability. Despite not being the closest planet to the Sun, it is the Solar System's hottest planet, engulfed by a stifling carbon dioxide atmosphere and thick clouds of sulphuric acid that trap the Sun's heat like a giant greenhouse. This leads to an average temperature of around 465 degrees Celsius (869 Fahrenheit), nearly three times hotter than Mercury's average. Despite its aggressive planetary persona, life on the second planet from the

Earth's extreme environments



Yellowstone Hot Springs

Wyoming, USA

Some natural sources in Yellowstone Park have such high levels of sulphuric acid, no life can survive there - except for certain bacteria, which thrive in the pools.

Key

- 01 Acidic
- 02 Thin air
- 03 Molten heat
- 04 Extreme dryness
- 05 Freezing cold

> "The answer to whether life ever got started on Mars, or perhaps is still there, may one day come from intricate and innovative missions"

High-atmosphere

10,000m (30,000ft) altitude

Recent experiments have shown that high up in Earth's atmosphere, where the air is thin, it's teeming with tiny bacteria and fungal spores.

Grímsvötn Volcano

Iceland

Some life thrives around the activity of a volcano, and bacteria have been found to breed quite happily in the boiling lakes kicked up by Iceland's grinding tectonics.

Atacama desert

Chile

Not much lives, grows or survives in the driest place on Earth outside of this desert's many telescope buildings, but just below the surface is a haven for bacteria.

Lake Vostok

Antarctica

In a subglacial lake situated in the coldest place on Earth, living bacteria have been found, locked beneath the ice for a countless number of millennia.

Planetary habitats

Mars

02 04

The Red Planet is very dry, has a thin atmosphere and once had running water on its surface. At the very least, it could have been a viable habitat for extremophile life.

Venus

01 03

We probably don't need to look as far as the crushing pressure and heat of Venus' surface: its clouds could be a perfect environment for acid-loving organisms.

Pluto

05

The dwarf planet is probably one of the most unlikely candidates for life in the Solar System and yet, scientists won't rule out the potential of its icy oceans.

Sun is not being ruled out. "Conditions high up in the cloud decks aren't dissimilar to Earth. They are very acidic, but we know from studies of extremophiles on Earth that life can survive such harsh conditions," Dartnell explains.

Bacteria have already been found living high in the atmosphere on Earth, at similar heights to where human beings are only found strapped into a pressurised aeroplane cabin. Despite the much thinner air, significantly lower temperatures and increased exposure to ultraviolet radiation, bacteria are abundant there, so it's not beyond the realms of possibility that the same is true of Venus. However, unlike Earth, any Venusian life would always need to maintain its altitude - drop too low and it would be crushed, baked and dissolved.

The key question, then, is where such life would have originated. Earth's lofty bacteria are likely to have started much closer to the surface before being carried to altitude. Conditions on the Venusian surface today are too harsh to cradle life, but that might not have always been the case. "Venus may have started out similar to Earth," says Dartnell. A runaway greenhouse effect - perhaps starting just a few billion years ago - then turned it into the hellish cauldron it is today. If life got started on Venus when conditions were more favourable, some of that life may still be clinging on in the only place it can: high up in the clouds.

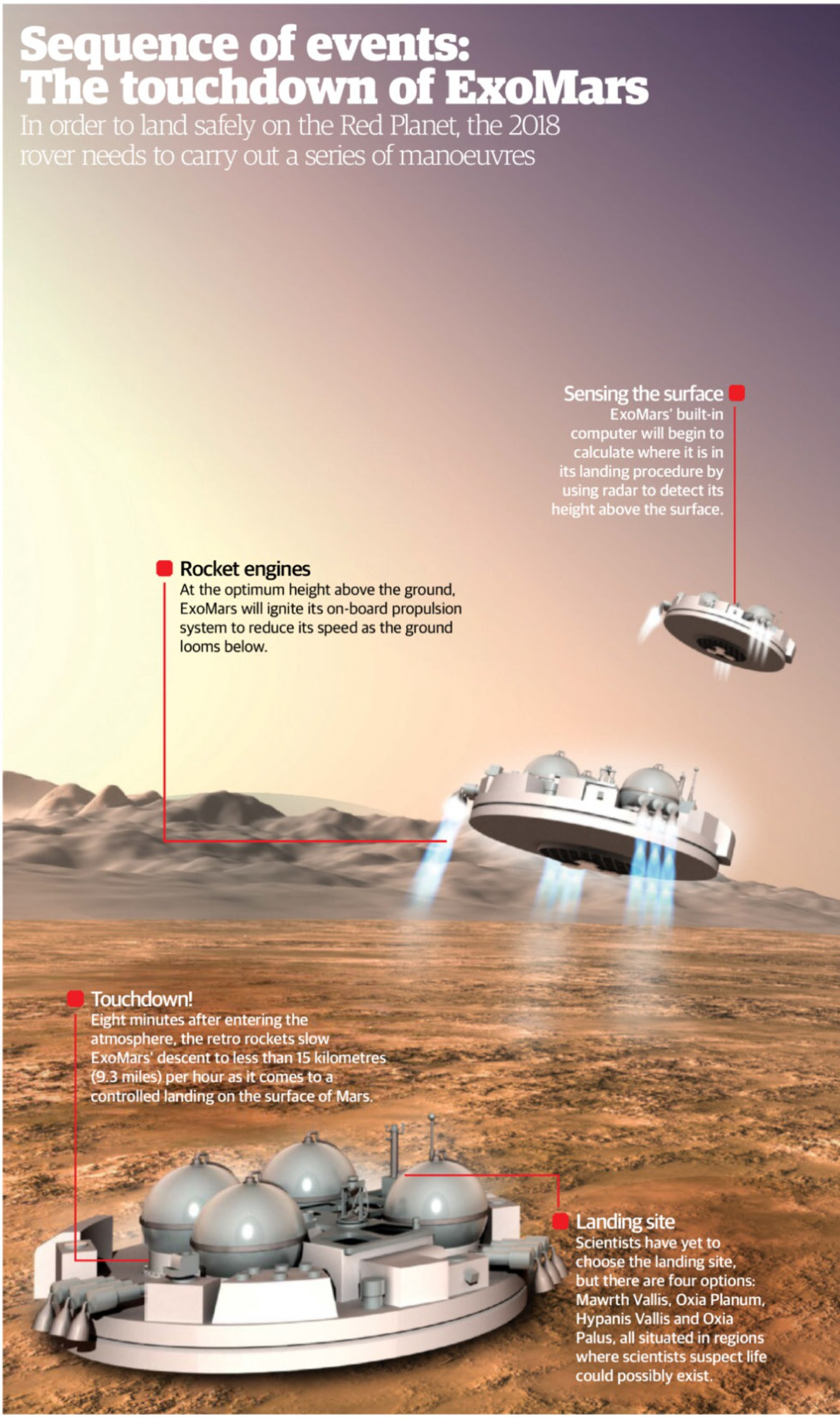
While bacterial life may be hidden away on the planets either side of us, our own planet is the one positively teeming with life. The extremophiles are an illustration of the broad range of environments life has colonised here. Almost all that life, from the tiniest bacteria to the biggest blue whale, has one thing in common: the need for liquid water. In this respect, Earth is in an ideal location. It isn't too close to the Sun, like Venus, where the temperatures soar and water evaporates. Nor do we orbit as far as Mars, where water is abundant but only persists for any length of time locked up in sprawling sheets of ice.

Our planet sits within the Sun's habitable zone - a thin ring of possible orbits that yields temperatures suitable for liquid water. Although not all astrobiologists agree, the alien-hunter's mantra is normally 'follow the water'. That has led to the search for alien life being extended beyond our Solar System and the hunt for Earth-like planets circling in the habitable zones of other stars. So far a total of nearly 2,000 confirmed exoplanets have been found, with a handful of them being rocky worlds in the habitable zones of their parent stars. Telescopes due to be launched in the next decade will be equipped with exquisite instrumentation capable of probing the atmospheres of these Earth-like alien worlds for signs of life. However, that doesn't mean the search is over in our own Solar System. Venus and Mars are only two of the places where life might exist, as water can be found far outside of the habitable zone too.

Given that water covers two thirds of our planet's surface, you might be forgiven for thinking Earth is the wettest place in the Solar System, but it isn't. That accolade goes to Europa, one of Jupiter's clan of 67 moons. Despite being smaller than our Moon, it is home to around twice the amount of water stored in all of Earth's oceans, lakes, seas and rivers. This water remains liquid despite being over 750 million

Sequence of events: The touchdown of ExoMars

In order to land safely on the Red Planet, the 2018 rover needs to carry out a series of manoeuvres

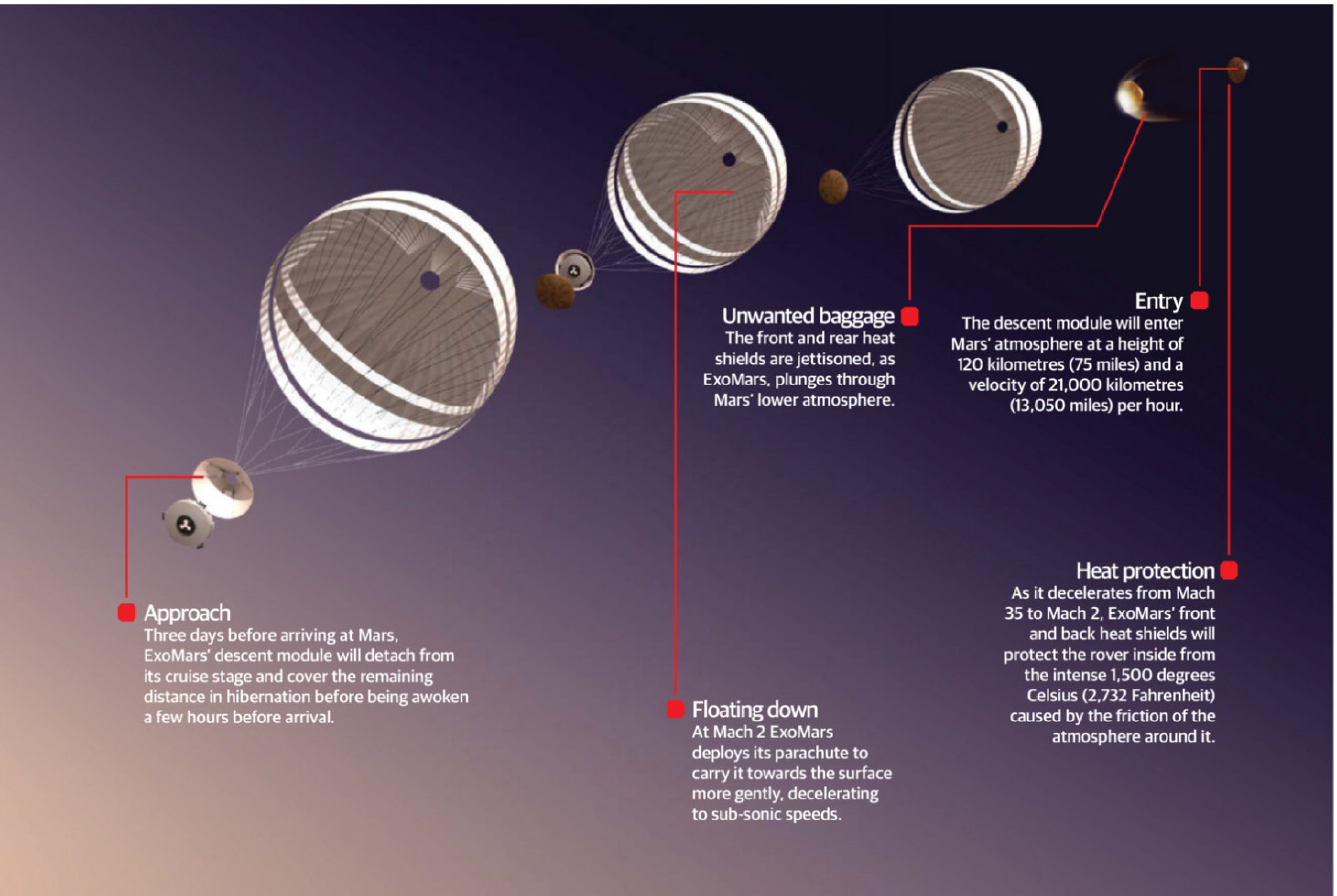


Sensing the surface
ExoMars' built-in computer will begin to calculate where it is in its landing procedure by using radar to detect its height above the surface.

Rocket engines
At the optimum height above the ground, ExoMars will ignite its on-board propulsion system to reduce its speed as the ground looms below.

Touchdown!
Eight minutes after entering the atmosphere, the retro rockets slow ExoMars' descent to less than 15 kilometres (9.3 miles) per hour as it comes to a controlled landing on the surface of Mars.

Landing site
Scientists have yet to choose the landing site, but there are four options: Mawrth Vallis, Oxia Planum, Hypanis Vallis and Oxia Palus, all situated in regions where scientists suspect life could possibly exist.



Approach
Three days before arriving at Mars, ExoMars' descent module will detach from its cruise stage and cover the remaining distance in hibernation before being awoken a few hours before arrival.

Entry
The descent module will enter Mars' atmosphere at a height of 120 kilometres (75 miles) and a velocity of 21,000 kilometres (13,050 miles) per hour.

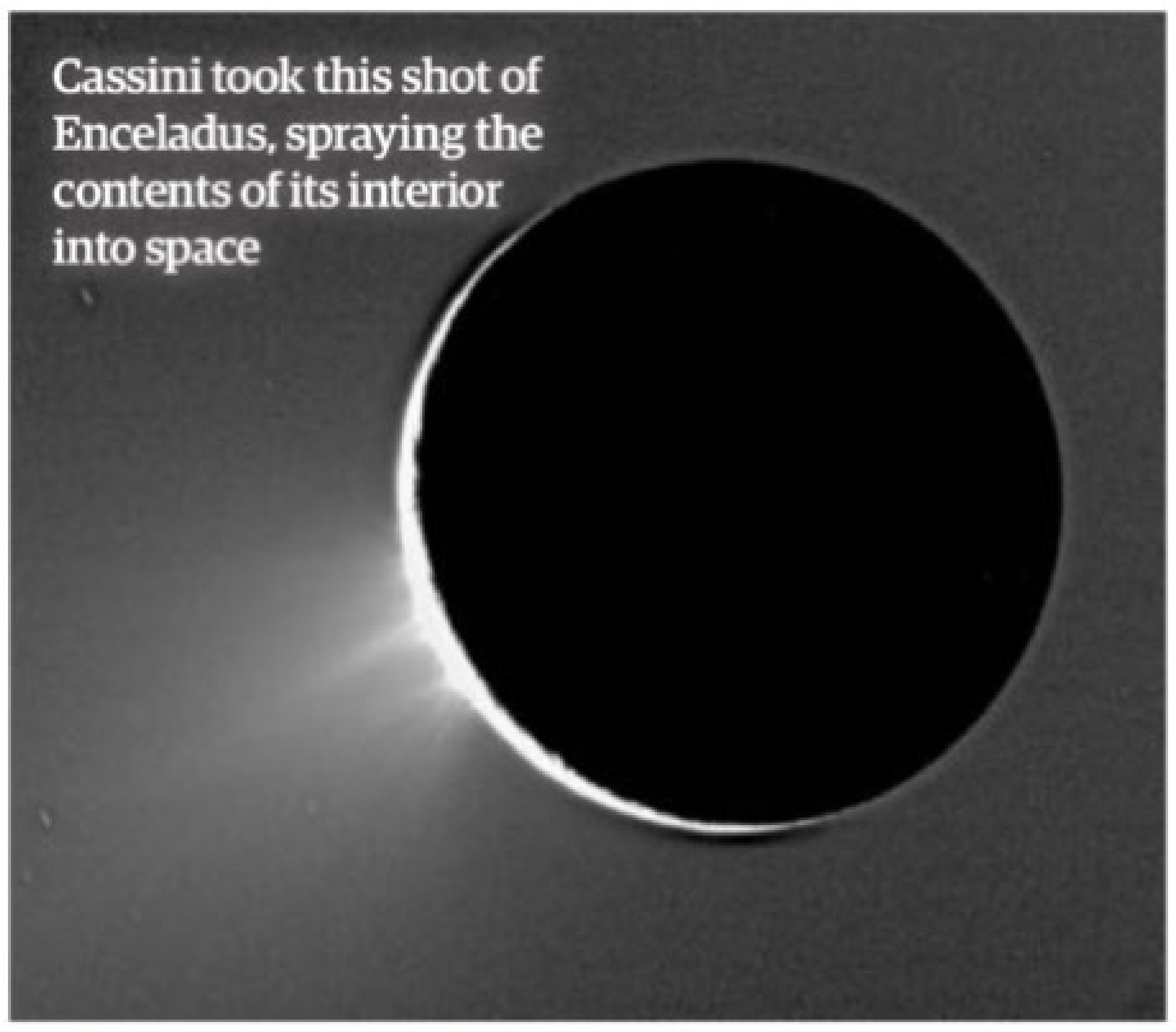
Heat protection
As it decelerates from Mach 35 to Mach 2, ExoMars' front and back heat shields will protect the rover inside from the intense 1,500 degrees Celsius (2,732 Fahrenheit) caused by the friction of the atmosphere around it.

Floating down
At Mach 2 ExoMars deploys its parachute to carry it towards the surface more gently, decelerating to sub-sonic speeds.

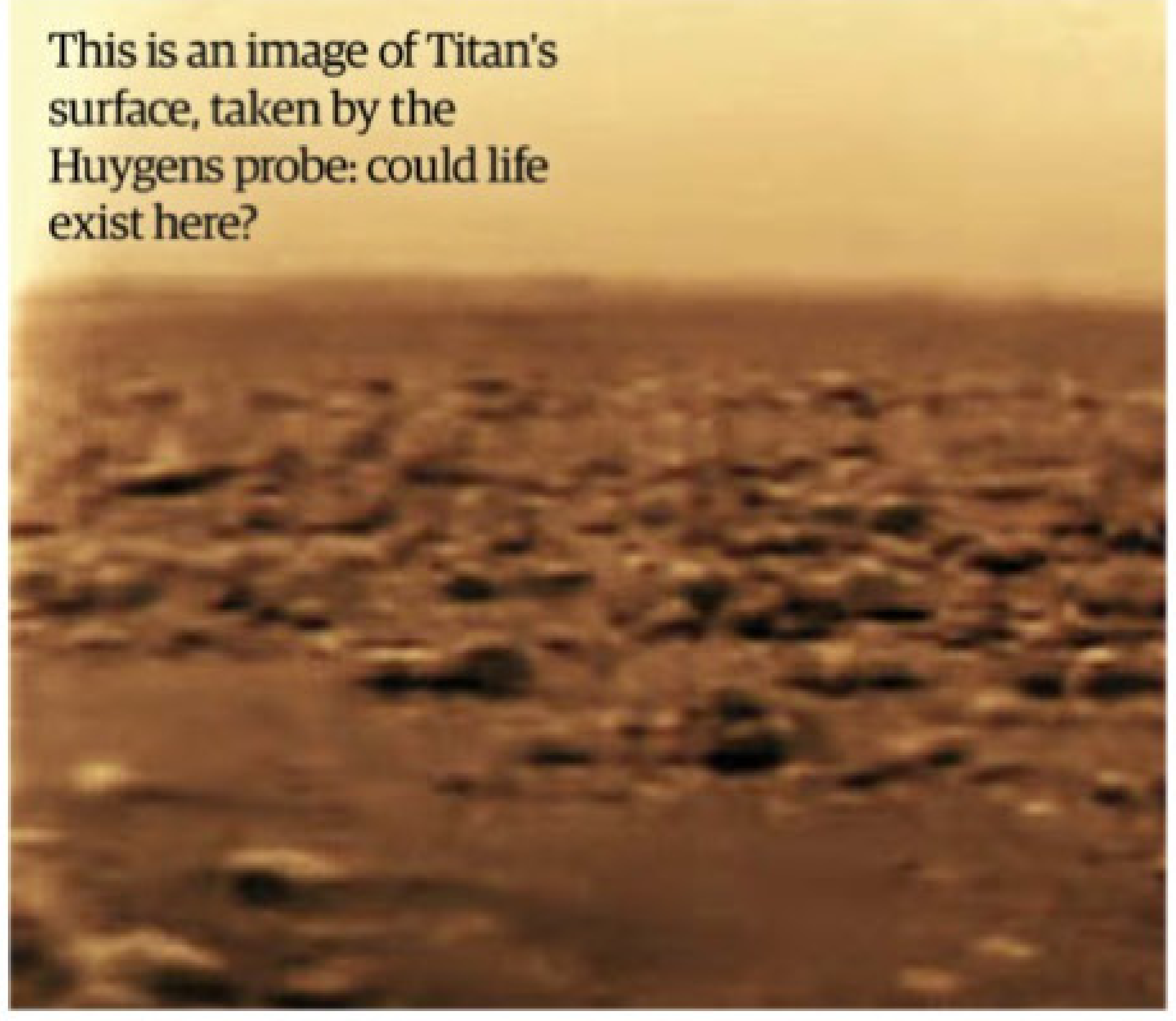
Unwanted baggage
The front and rear heat shields are jettisoned, as ExoMars, plunges through Mars' lower atmosphere.

The ExoMars rover, shown here as a prototype, will drill into the surface of the Red Planet in the search for life

The Crybot is a probe that can penetrate kilometres-deep ice crusts to explore what's lying the oceans below



Cassini took this shot of Enceladus, spraying the contents of its interior into space



This is an image of Titan's surface, taken by the Huygens probe: could life exist here?

> "It's unclear whether liquid methane can be as effective a solvent for structures like DNA as water is on Earth"
>
> **Dr. Lewis Dartnell**

kilometres (466 million miles) from the Sun – more than three times further away than the outer edge of the habitable zone. It's not our star keeping the water warm at this otherwise frigid distance, but Jupiter. Europa orbits the giant planet in just three and a half days and is mercilessly pummelled by Jupiter's immense gravity as it goes. This gravitational flexing injects enough energy into the moon's core to maintain a sizeable ocean of liquid water. The colossal gravitational tidal forces it experiences means Europa's subsurface ocean can rise and fall by as much as 500 metres (1,640 metres). The ocean is shielded from the vacuum of space by vast sheets of ice, which sport gaping cracks called lineae, caused by the Europan ocean sloshing around beneath it and cracking it up.

Any life existing in the subterranean water would be hidden away from what little solar energy reaches this part of the Solar System. That isn't necessarily a problem, because life has been found deep in our own oceans receiving no sunlight whatsoever. Instead, its energy supply is the stream of minerals seeping out of cracks in the Earth's crust on the ocean floor. Tidal heating by Jupiter may cause similar hydrothermal vents on Europa's seabed and there could even be a supply of oxygen too. One study suggests that cosmic rays hitting the surface of the ice could split some of the water into oxygen and hydrogen, some of which could end up in the cracks and filter down into the ocean below. Some questions need answering first, however. "It all depends on how thick that ice is and at the moment we simply don't know," says Dartnell. The presence of so much liquid water has led to numerous calls for scientists to send a mission to land on the ice and explore. While no such lander is currently planned, ESA hopes to launch the Jupiter Icy Moons Explorer (JUICE) in 2022 with the intention of flying close to Europa.

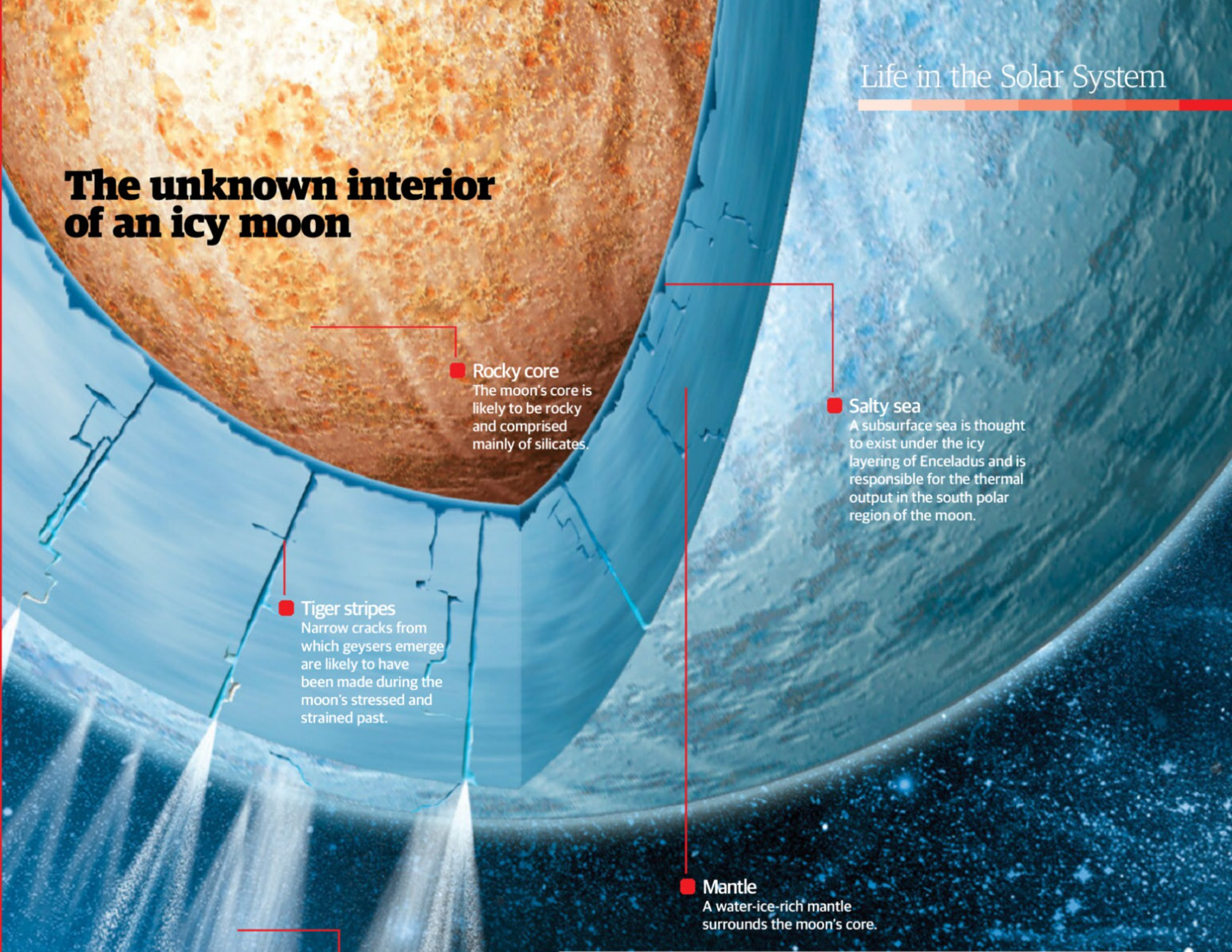
The only mission to have done that so far is the Galileo probe, launched in 1989. Ever since, the small moon has commanded the lion's share of attention when it comes to habitable moons in our Solar System. But of late an even smaller, more-distant satellite – Saturn's Enceladus – has been quietly climbing the list. In 2005, the Cassini probe caught the moon spewing water plumes into space from its south pole. The water seems to be coming from four giant fissures in the moon's surface known as tiger stripes, which have been named Baghdad, Cairo, Alexandria and Damascus. Over a hundred such fountains have since been identified and it's thought that together they eject water at the rate of 200 kilograms (440 pounds) each second.

Results published by the Cassini team suggest these jets are coming from an ocean of water tucked away under the moon's icy crust. "There is enough water there to fill Lake Superior here on Earth," says lead author Luciano Iess from the Sapienza University of Rome. So, could such an ocean be home to life? "I think Europa is a better bet than Enceladus," says Dartnell. "But Enceladus is easier to sample." As Enceladus throws some of its water into space, it's easier to access than the ice-shrouded ocean on Europa. Missions could fly through the Enceladean plumes and collect material, even returning it to Earth for detailed analysis, whereas sampling the Europan ocean would require manoeuvres.

Landing a spacecraft on the surface of an object in the outer Solar System is no mean feat. In fact, it has only been tried once before: in January 2005, the Huygens probe settled down on the surface of Titan. Saturn's largest moon and the second largest in the Solar System, Titan is bigger than the planet Mercury and it's also the only moon known to have a thick atmosphere. Like Venus, that atmosphere makes observations of the surface very difficult, so Huygens was sent through the clouds to investigate. Its findings have implications for the chances of finding life there.

Like Earth, Titan plays host to lakes, rivers and seas. It has islands, coastlines and archipelagos, yet this intricate system is not sculpted by liquid water,

The unknown interior of an icy moon



Rocky core
The moon's core is likely to be rocky and comprised mainly of silicates.

Salty sea
A subsurface sea is thought to exist under the icy layering of Enceladus and is responsible for the thermal output in the south polar region of the moon.

Tiger stripes
Narrow cracks from which geysers emerge are likely to have been made during the moon's stressed and strained past.

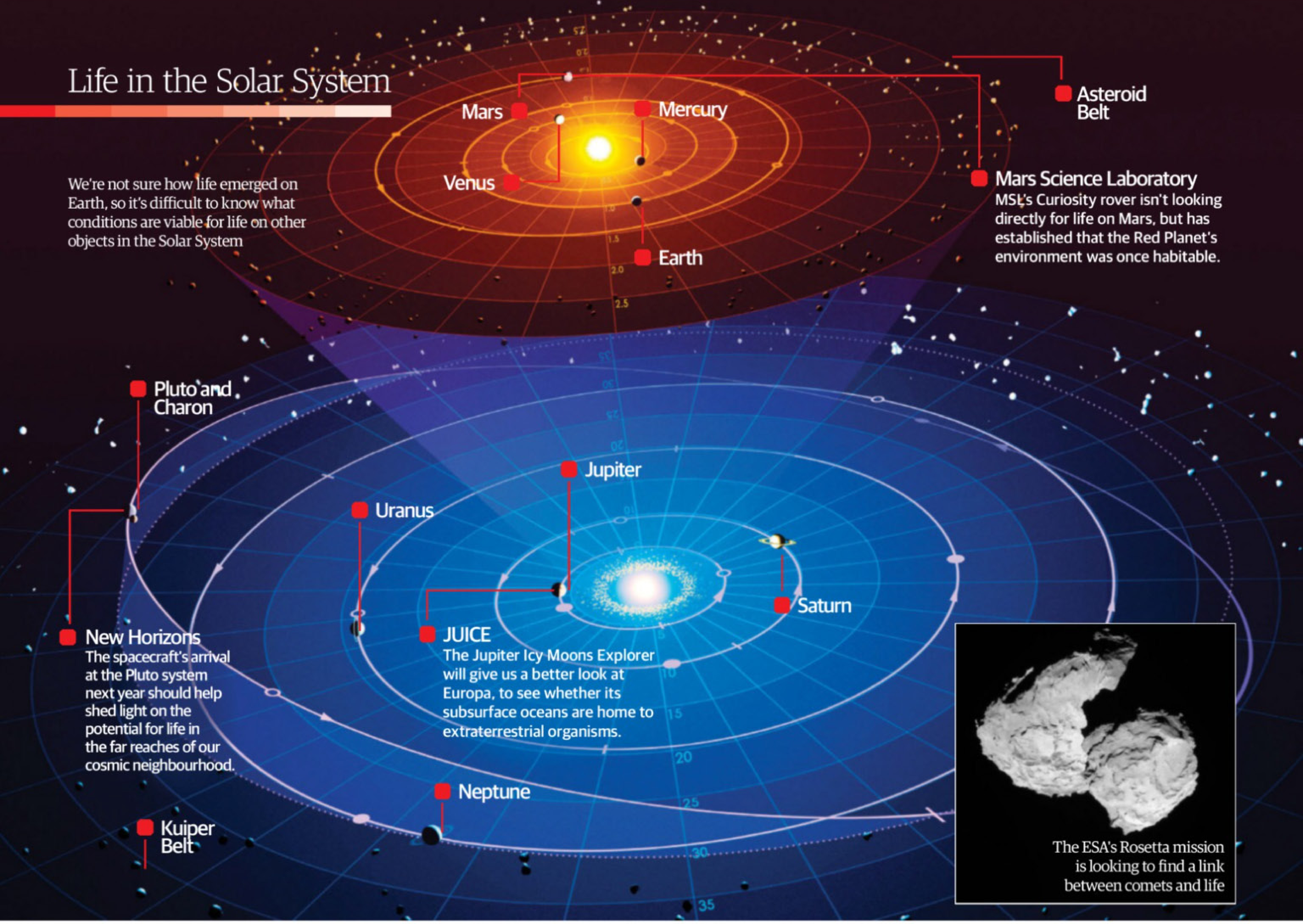
Mantle
A water-ice-rich mantle surrounds the moon's core.

Geysers
Liquid water under pressure is drawn up through the brittle layers of ice, allowing the subsurface to reach the surface as hot vapour and water droplets.

Saturn's Enceladus, a moon of icy volcanic flows commonly known as geysers, is one of the worlds astronomers are targeting when it comes to looking for life

Life in the Solar System

We're not sure how life emerged on Earth, so it's difficult to know what conditions are viable for life on other objects in the Solar System



Mars Science Laboratory
MSL's Curiosity rover isn't looking directly for life on Mars, but has established that the Red Planet's environment was once habitable.

New Horizons
The spacecraft's arrival at the Pluto system next year should help shed light on the potential for life in the far reaches of our cosmic neighbourhood.

JUICE
The Jupiter Icy Moons Explorer will give us a better look at Europa, to see whether its subsurface oceans are home to extraterrestrial organisms.

The ESA's Rosetta mission is looking to find a link between comets and life

> "We still have a lot of work to do in order to understand what makes a suitable habitat for life"

but by liquid methane, which rains down to the surface as water does on Earth. Hydrocarbons – the building blocks from which life is constructed – have also been spotted. However, it remains to be seen if life can develop under such alien circumstances. "It's unclear whether liquid methane can be as effective a solvent for structures like DNA as water is on Earth," says Dartnell.

Titan still has liquid water – it just isn't on the surface. In July 2012, scientists using five years' worth of Cassini data found evidence that the moon probably has a sub-surface ocean comprised of liquid water and ammonia. It's thought this reservoir is incredibly salty, perhaps as salty as the Dead Sea here on Earth. But once again extremophiles have shown us that life can adapt to high salinity, particularly if the water was less salty in the past. "It would make Titan a unique place, perhaps with not one biosphere, but two," says Dartnell. If this is the case, it is possible that these two ecosystems could have developed entirely independently of each another.

If chemicals other than water are being considered as solvents capable of sustaining life, another world to look at might be Triton – Neptune's largest moon. The temperature here plummets to just -235 degrees Celsius (-391 Fahrenheit), too cold even for methane to remain liquid. However, it's believed that an ocean exists beneath its icy crust. Ice volcanoes on the surface eject what scientists believe to be liquid nitrogen and methane. Hydrocarbons are thought to exist here too, although that might not be enough to make the moon habitable. "Triton is the outside bet because no one knows if liquid nitrogen can sustain life," says Dartnell.

What makes Triton particularly interesting is that it's the only sizeable moon in the Solar System to orbit its planet backwards – in the opposite direction to the spin of its host. It's very hard to envisage how such a big moon could have formed spinning backwards around its planet, so the leading theory is that Triton was captured by Neptune's gravity some time after the planet formed. The moon's most likely birthplace is the Kuiper Belt – an area of icy bodies that includes the dwarf planet Pluto. This region is home to at least twenty times more material than the Asteroid Belt between Mars and Jupiter. Beyond the Kuiper Belt sits the scattered disc – the origin of short-period comets such as the famous Halley's comet. Studies of both comets and asteroids have shown that they contain complex organic molecules that might be capable of acting as the building blocks for life. Missions like ESA's Rosetta – which linked up with comet 67P/Churyumov-Gerasimenko after a ten-year, 400-million-kilometre (250-million-mile) journey – hope to discover more about the link between comets and life.

During the Solar System's youth, its planets and moons were battered by a deluge of comet and asteroid impacts over an era known as the Late Heavy Bombardment period. Objects like Mercury and the Moon still bear the scars of these collisions today. It's possible that they even seeded the infant Earth with the right range of chemicals from which life would later develop. If that is true, then it's very likely other places in our Solar System were seeded too. The answer to the question of whether those seeds turned into living organisms elsewhere has been the driving force behind much of our exploration of our local space neighbourhood so far, and will continue to be in future.

However, our searching to date has shown that we still have a lot of work to do in order to understand what makes a suitable habitat for life. Earth is still the only place we know of capable of supporting living things, yet we still don't even know for sure how life on our planet began. Knowing what turned a set of inanimate chemical ingredients – possibly delivered by comets – into something we'd describe as living, would be a big step in determining whether that has happened on other worlds, both in our Solar System and even beyond. ■

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5 Amazing facts

Hot Jupiters

They can melt solid silver

These massive exoplanets orbit very close to their parent stars and can hit temperatures in excess of 1,000 degrees Celsius (1,832 Fahrenheit) at their daytime surfaces. That's hot enough to melt many elements and some metals, including lead and silver.

Hot Jupiters were never predicted

Despite making up an estimated fifth of all known exoplanets and being the first such worlds to be confirmed, hot Jupiters were a complete surprise to scientists. Their planet-formation models never predicted planets of this type – a sort of bonus in the search for Earth-like planets.

They're slowly boiling away

Hot Jupiters are gas giants, so their proximity to a nearby star heats the gas at the surface, causing it to expand and boil off the planet, leaving a trail in its orbit. It's thought that the hot Jupiter HD 189733b, found 63 light years from Earth, is losing 100 million to 600 million kilograms (220 million to 1,323 million pounds) of mass every second.

Scientists can easily locate them

Hot Jupiters block out a lot of light when they pass in front of their parent star, and their close orbits mean they travel in front of the star more often over any given period. Their huge gravity also causes their star to wobble, making them easier to detect.

Deadly rain falls on their surfaces

Some hot Jupiters don't appear red to the naked eye. Scientists think that silicate particles in their atmosphere make them look blue and that these particles are melting in the oppressive heat of the atmospheres, to form a lethal rain of molten glass.

Hot Jupiters heat up so much, they leave a trail of boiled gas in their wake as they orbit their star

© ESA, Hubble

MAVEN's mission to Mars

The MAVEN mission's principal investigator Bruce Jakosky and instrument manager Mark Lankton chat to All About Space about the spacecraft's impending arrival at the Red Planet

Interviewed by Gemma Lavender

INTERVIEW BIOS

Bruce Jakosky
Bruce Jakosky is the principal investigator of MAVEN and has been involved with other missions such as Viking, Solar Mesosphere Explorer, Clementine, Mars Observer, Mars Global Surveyor, Mars Odyssey and the Mars Science Laboratory.

Mark Lankton
Mark Lankton is a project manager at the University of Colorado Laboratory for Atmospheric and Space Physics. He's also the remote sensing package program manager for MAVEN and has managed many teams and instruments for many other space missions.

Could you explain a bit about your roles on the MAVEN mission?

Bruce Jakosky: I'm in charge of the whole project. The idea for proposing this started about 11 years ago and it was a conversation that I had with two of our science team members. My role is to oversee all aspects of it, to make sure that the science and engineering meld well together and that the system we have designed and built can actually get the science results we want. I also oversee all aspects of the operations and the science analysis…

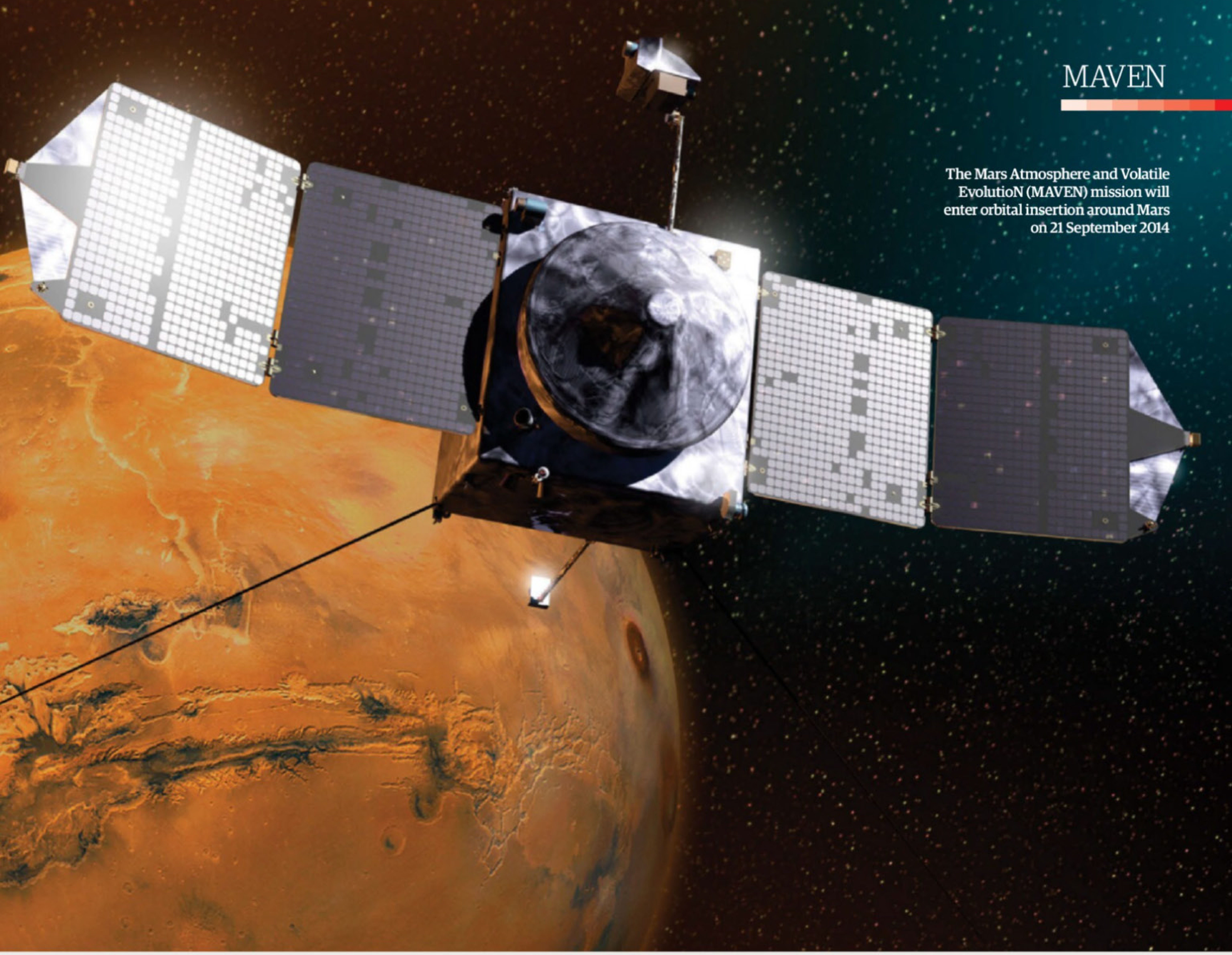
Mark Lankton: My job was to manage the team that built one of the science instruments. This is what we call the remote sensing package, which is basically an imaging ultraviolet spectrograph and all the electronics that goes with it. We designed, built, tested and then delivered this remote sensing package to the spacecraft and I really enjoyed that work…

Were there any major challenges for the team?

BJ: [Laughs] Let me be honest, building a spacecraft like MAVEN is an interesting mix in the sense that everything we did to develop, build, test and launch it we've done before and we know how to do very well. In that sense it's very straightforward. Yet at the same time, the space environment is very harsh and it's really easy to do things as you're designing and building that will screw it up. It's very easy to damage the hardware, or to build something that isn't robust enough to operate in space…

Space is a very difficult business to be in and so far we've been lucky in that the spacecraft and the instruments have all been working – but we're not there yet. We have a lot of activities that we have to carry out before we can do science, including getting into orbit, deploying our booms and making sure that the instruments are still working. Only then will we actually be able to do the science we've carried out.

ML: Speaking for our instrument, things went fairly smoothly but you're always building something that is about as complicated as you can handle, so it's always interesting. Maybe the most interesting feature of our instrument is that it has both a high-resolution and a low-resolution mode, so it's almost like two spectrographs in one. You do this by using some mechanisms to put one diffraction grating in place of another and this is in the middle of the instrument. So when you try and get everything aligned and measure how it is working, you have a telescope up front and a set of light detectors at the back and two different



The Mars Atmosphere and Volatile EvolutioN (MAVEN) mission will enter orbital insertion around Mars on 21 September 2014

"Space is a difficult business to be in and so far we've been very lucky"

paths through the middle and they each have to work independently. When you switch from one to the other, everything still has to be in place and that was interesting. I don't think we can say we had trouble with it, but we certainly worked hard to make it work.

MAVEN is almost at Mars. What are you looking forward to most when it reaches the Red Planet?
BJ: Well, we've been developing the mission for 11 years now and it all comes down to the Mars orbit insertion – that's an absolutely necessary step that has to be carried out successfully in order to continue. So of course, right now, we're focused on just getting into orbit successfully and then beginning to check out the instruments. The long-term emphasis is on the mission, but right now all eyes are on the orbit insertion. We don't want to be looking beyond that.

Do you feel a bit nervous?
BJ: [Laughs] Oh, very much so! I'm turning into a basket case! It was like that at launch – I was very nervous. The odds are that it will go absolutely perfectly, but you want to make sure that you've covered every contingency. Nervousness helps you to focus on what needs to be done.

ML: It has been proven that Mars missions are not always successful, so I guess I would say I am confident but alert. I have a lot of confidence in the team flying the spacecraft… and I know they are confident but also very alert.

How tricky will MAVEN's manoeuvres into Mars orbit be and what if something goes wrong?
BJ: Well, the most likely scenario is that everything will go exactly as planned – at least that's what I keep telling myself! We have taken all of the precautions to ensure things go well [but] the spacecraft has to be on its own. The response time of the spacecraft, if we were to send a command, is 25 minutes and it will be too far for us to be able to control anything… We've tried to identify all of the things that we think could go wrong and to program into the spacecraft the commands of what to do if something does happen.

Scientists and engineers from Lockheed Martin, University of Colorado Boulder, University of California, Berkeley and NASA all helped with MAVEN's launch

MAVEN's payload fairing, seen here at NASA's Kennedy Space Center, is a nose cone that was used to protect against pressure and heating

> "We're studying one of the most ignored Mars components up until now and it's one that we really need to understand"

So for example, if the computer that controls the orbit insertion burn has a hiccup during the process, it can automatically reboot. If that doesn't solve the problem, it can automatically switch to the backup computer.

Why doesn't MAVEN have a camera?

ML: As you can imagine it was a topic of a lot of debate, because there's always a camera, right? But in this case we were working with a finite amount of money and we were trying to do the most specific atmosphere-type science that we could do for that amount of money. So for the measurements we're trying to make, the science of how the atmosphere is working and escaping into space, a camera would have been a thrill. I hate to say it that way because it would have been fascinating to see the pictures in visible light as we flew by, but it would not honestly have helped the science. So as good taxpayers we said:"No we're going to build the instruments we need to build and that's it." But it certainly got discussed a lot.

How will the remote sensing package measure Mars' atmosphere?

ML: The remote sensing package is different from most of the other instruments [that] make their measurements as the spacecraft flies through the very thin upper atmosphere – it's like sticking your hand out of the car window and grabbing some air.

What we built is different. We call it remote sensing because you are looking a long way away and rather than sampling the atmosphere and tasting it, you're looking at the ultraviolet light that is coming from chemical reactions in the upper atmosphere. So we will fly around Mars in the closer parts of the orbit and will look at the little pile of atmosphere out there on the horizon and we'll look at the ultraviolet light coming from there.

By looking at the emissions at specific wavelengths of that light we can tell if there's carbon dioxide out there, if there's carbon monoxide out there, or just a range of chemical reactions among the constituents of the atmosphere. The way it works is that sunlight will excite the atoms and molecules in the atmosphere and when they go back to their normal state they emit UV photons.

Why is it important that we learn more about Mars' atmosphere?

BJ: The emphasis of this mission is on trying to understand the history of the atmosphere and the driver really is to understand the geological and potential biological history of the planet. We see a lot of evidence that the climate on Mars has changed over time. For example, we see geological evidence from liquid water early on, yet the water disappeared – we just see cold, dry ice on the planet today. What conditions allowed water to present as a liquid early on? Most people think that there had to be a thicker greenhouse atmosphere, so the question immediately becomes: 'Where did the water go and where did the carbon dioxide from a greenhouse atmosphere go?'

So we're studying the upper atmosphere as a way to answer those questions because loss of the gas to space is one of the processes that we think was very important. What we want to do is understand how important that process was and to determine whether loss to space out the top of the atmosphere was perhaps even the dominant process in the history of the atmosphere and the changing climate. That's going to tell us a lot about what controls the geological history of Mars and what controls its habitability.

Will you compare notes with India's Mars Orbiter Mission (MOM), which arrives two days later?

BJ: We want to collaborate, we're friends with some of those people and we want to be able to work together. We've started some discussions with the MOM science team on ways we might be able to collaborate on data analysis but we haven't got too far yet… We're rooting for them for a successful mission and we know that they're rooting for us.

Comet Siding Spring is going to be making a close approach to Mars in October. Will it also make a close approach to MAVEN?

ML: It's close in a way – close enough to be interesting for sure. It would be a great opportunity but it's also a risk. We're not going to commit suicide just to get a better look at the comet. We've arranged things so that from our place in orbit we're mostly protected from any potential interactions with Siding Spring... What we would not want to happen is for little pieces of the comet to actually hit the spacecraft. On the other hand, of course, we're interested in this wonderful celestial phenomenon.

There are some planned observations using the remote instrument package to see what will happen to Mars' atmosphere as the comet flies by. However, this is not prime MAVEN science - but as you have the opportunity you might as well turn on the instrument and have a look.

What's MAVEN doing at the moment?
BJ: We've quietened things down on the spacecraft, turned off all of the science instruments, so we're not taking measurements. We're not even doing any testing of the components of the spacecraft - we've done that. We're trying to keep it quiet so that we don't do anything to inadvertently hurt the spacecraft...

Will MAVEN be working with the rovers on Mars?
ML: There may be a connection that someone can make, but the observations are not co-ordinated in any way that I am aware of. The rovers are very much concerned with what is right on the surface and, although there is some correlation to what is right on the surface to what is way up in the atmosphere, we are not trying to co-ordinate our timing or anything like that... It is different science.

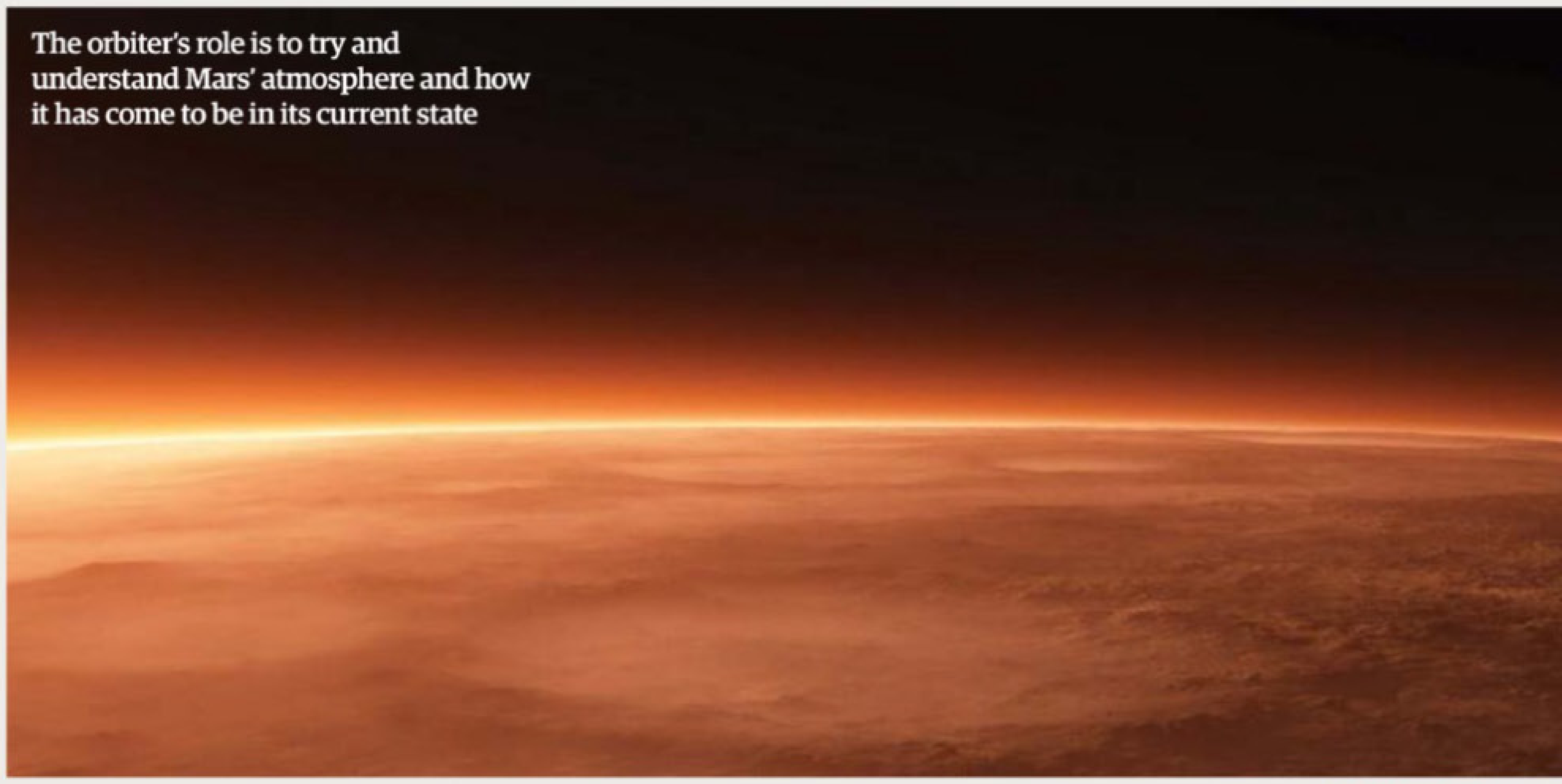
What will happen to MAVEN when the mission ends? Will it just fall into Mars' atmosphere?
BJ: Eventually, that is what will happen. The orbit we're in for our science mission is an elliptical orbit and in that elliptical orbit we get down to low enough altitudes that we're passing through the planet's upper atmosphere. Even as tenuous as it is, there's enough drag to cause the orbit to decay and it's preferable that the fate of the spacecraft is to hit the surface.

ML: We'll be in a high orbit and we'll just stay in that high orbit, but at some point we wouldn't be able to control the spacecraft anymore. If you don't know where you're pointed, then you're done doing science.

Recently we've been sending rovers to Mars. Why have we gone back to the orbiter?
BJ: You have to think back to what the science questions are that we're asking of Mars and that relate to the geological side of history, the climate history - whether there's life on Mars.

We've learned, as we've tried to answer these questions, that the Mars environmental system is very complex... If we want to understand what happened on Mars, what the history of the planet has been, we need to understand all of the different aspects of the system. We're sending MAVEN as an orbiter in order to understand the top of the atmosphere and how it interacts with the Sun and solar wind.

We think this is an important process in controlling the history of the planet and we think that's a vital component of the Mars environmental system. MAVEN is the first spacecraft devoted to understanding it, so what we need to do is send spacecraft to understand all of the different components of the Mars environment. We're studying one of the most ignored Mars components up until now and it's one that we really need to understand. ●


The orbiter's role is to try and understand Mars' atmosphere and how it has come to be in its current state

Bruce Jakosky, the principal investigator for MAVEN
MAVEN
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The team behind the MAVEN mission poses for a group photo

Technicians at work on MAVEN's nose cone prior to assembly

India's Mars Orbiter Mission (MOM), which launched in November last year, will reach Mars at around the same time as MAVEN

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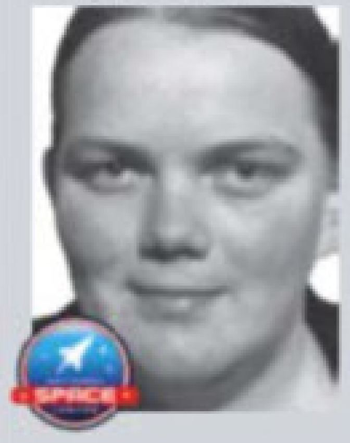
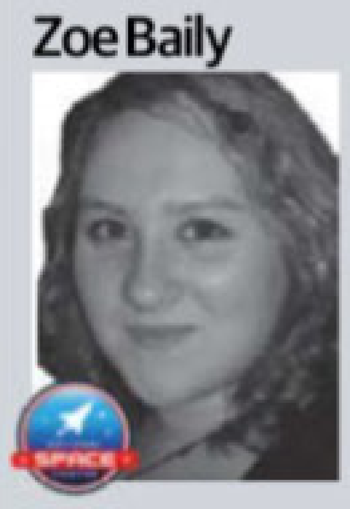
Sophie Allan



National Space Academy Education Officer

■ Sophie studied Astrophysics at university. She has a special interest in astrobiology and planetary science.

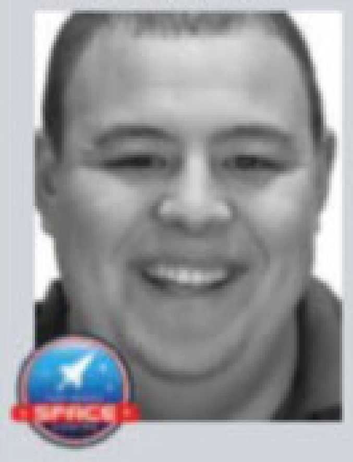
Zoe Baily



National Space Centre

■ Zoe holds a Master's degree in interdisciplinary science and loves the topic of space as it brings together many different scientific disciplines.

Josh Barker



Education Team Presenter

■ Having achieved a Master's in Physics and Astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

Gemma Lavender

Senior staff writer

■ Gemma has been elected as a fellow of the Royal Astronomical Society, is a keen stargazer and telescope enthusiast on **All About Space** magazine.

SPACE EXPLORATION

How many elements have been found that are unknown on Earth?

Sophie Davies

We haven't identified any elements that we haven't found occurring naturally or created on Earth.

A chemical element is defined by the number of protons in an atom's nucleus – this is called its atomic number. When the Periodic Table was first created, it had missing elements but since then we have been able to fill in the gaps. It isn't possible to have an atomic number that isn't a whole number, so we know that we have managed to fill all the spaces. The only new elements that could be discovered would be those with higher atomic numbers than any we have previously discovered on Earth.

Heavier elements are created by nuclear fusion reaction, just like those at the core of stars. Many of the heavier elements in the Periodic Table don't occur naturally and so can only be created by scientists. This would seem to suggest that we're unlikely to find new elements out in space any time soon. **ZB**

Have we identified any elements that we can't find on Earth?

DEEP SPACE

What could antimatter look like?

Carlos Gomez

Theoretically it is thought that something made out of antimatter would not look any different to its counterpart, made out of matter, but as of yet we don't know for sure.

Following the particle physics theory, antimatter is made of the antiparticles of its matter equivalent. Antiparticles are the same as their counterparts, only they hold the opposite charge. So far we have only been able to create very simple forms of antimatter, such as an anti-hydrogen atom and an anti-helium nucleus. The problem with finding out what this antimatter would look like is that any exposure of antimatter to matter causes both to be annihilated. Because of this we've only been able to observe just a few particles of antimatter for a few minutes at a time. **SA**

It's thought that both matter and antimatter are propelled almost to the speed of light by the Crab pulsar

ASTRONOMY

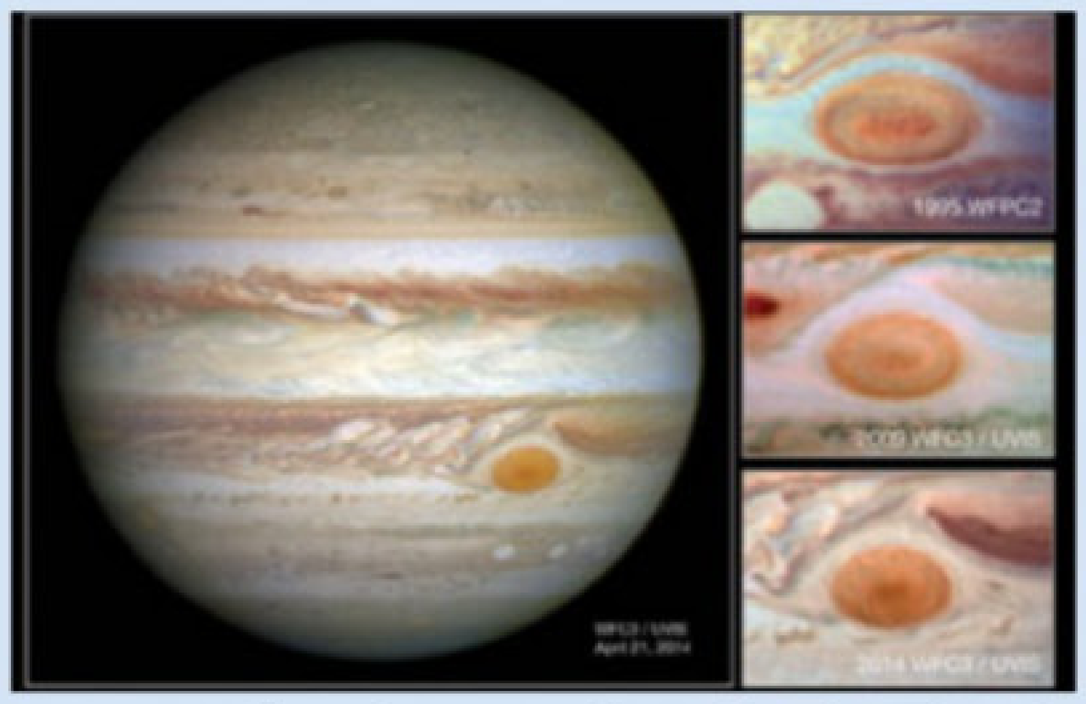
How can I correct spherical aberration on my telescope?

Janet Bannister

Spherical aberration is a tricky effect that's primarily caused by imperfect lenses. It can have a large affect on the clarity of images received through any lensed optical device, such as a telescope. In a multi-element construction, most of the spherical aberration should have been corrected for and manipulation of the lens setup may help reduce it further.

Another way to minimise spherical aberration is to reduce the aperture of your device. Spherical aberration most affects rays of light passing through the edge of a lens or striking the edge of a mirror. The further from the optical axis, the greater the aberration. By limiting and reducing the aperture we only draw from rays striking closer to the optic axis, thus reducing the errors caused by any aberration. **JB**

Reducing your instrument's aperture could help to reduce spherical aberration



Jupiter's trademark Great Red Spot has shrunk and taken on a more-circular appearance

SOLAR SYSTEM

Why is Jupiter's Great Red Spot changing shape?

Henry Michaels

Jupiter's famous Great Red Spot, a swirling anti-cyclonic storm that's bigger than Earth, has shrunk in size and it's thought that the down-sizing could be caused by small eddies feeding into the gas giant's trademark feature. However, this is just speculation.

Observations taken by the NASA/ESA Hubble Space Telescope have recently revealed that the storm, which was once an oval, is now quite circular and measures just under 16,500 kilometres (10,253 miles) across. That's quite a contrast in comparison with its former widest point, which once spanned 41,000 kilometres (25,476 miles). It was previously big enough to fit three Earths inside.

Astronomers have always known that Jupiter's spot would reduce in size and, since 2012, the storm is getting smaller by around 1,000 kilometres (621 miles) per year. **GL**

Astronomical filters should work on a pair of binoculars, however, it might not be practical to attach them!

ASTRONOMY

Can I use astronomical filters on my binoculars?

Astronomical filters simply filter light to make it easier to view certain celestial objects, so they should work regardless of what they're attached to. If you can view the light passing through it, the filter will do its job.

This means that, theoretically, they should work fine with your binoculars, but practically it may not be quite as straightforward.

Usually astronomical filters are designed to fit between the telescope and the eyepiece and, as such, have a specific configuration. Unfortunately this may not fit on to your binoculars as easily as you'd like.

Another problem is that often binoculars have a very wide field of view compared with telescopes. This could result in multiple objects being visible, which could affect the filter's performance or perceived quality. Also bear in mind that you'll need two of each filter! **GL**

The starshade should help find planets that are otherwise too small to see next to their bright parent star

SPACE EXPLORATION

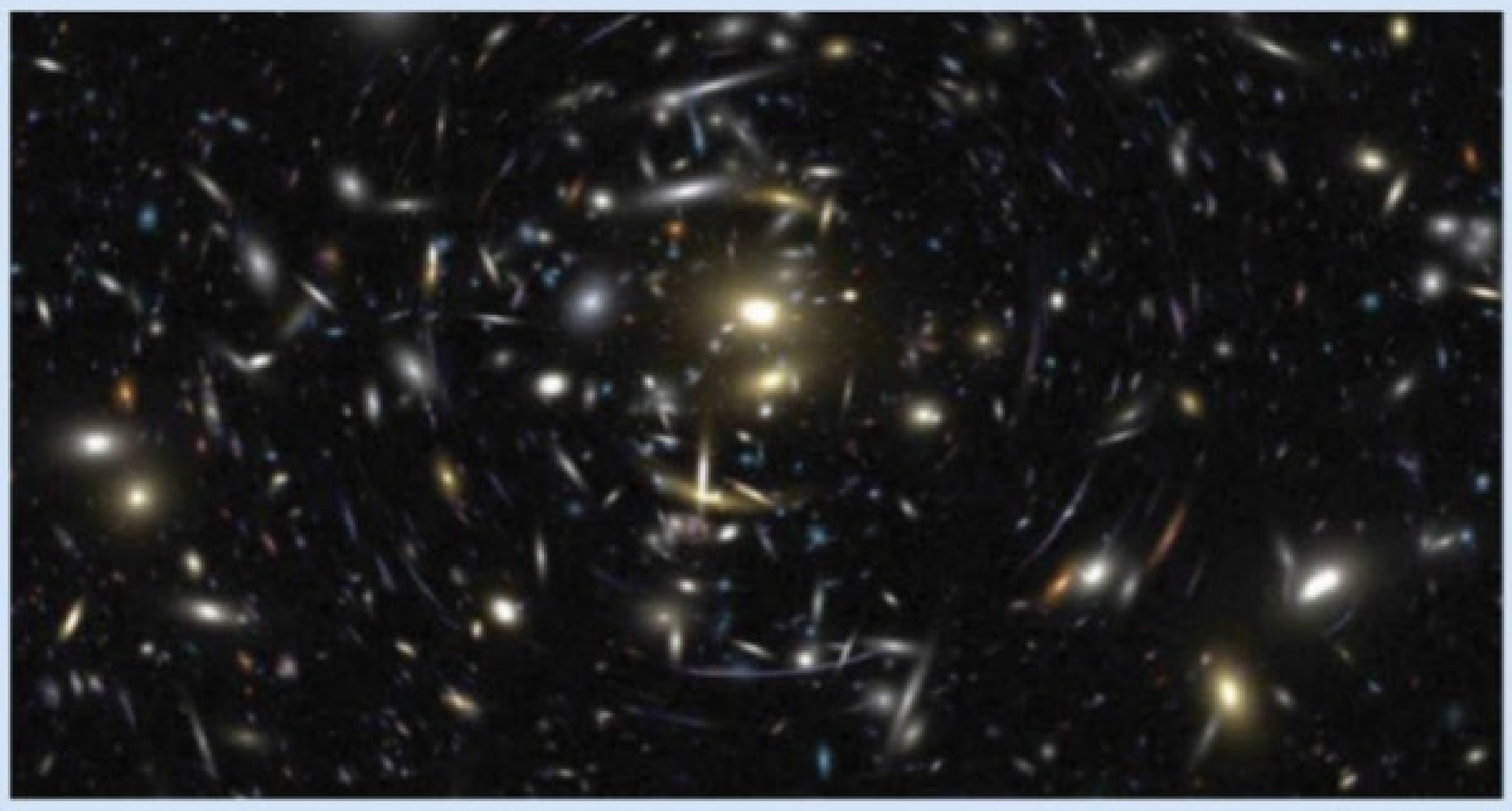
What will NASA's starshade help astronomers to achieve?

Tom Corfield

The starshade would launch into space alongside a space telescope and would help astronomers get a clearer view of planets orbiting around other stars. In space the starshade would be positioned in front of the telescope to help block out the majority of light from a faraway star.

The search for Earth-like planets outside of our Solar System has been going on for many years. We have managed to spot thousands of exoplanets around other stars but we have yet to find a perfectly Earth-like twin.

Part of the problem may be that Earth-like planets are just very difficult to spot, as they are small and close to their parent star. If there are Earth-like planets out there, this new starshade concept may make them easier to find. **ZB**



The furthest galaxies from the Milky Way are not what they seem

DEEP SPACE

What do the most-distant galaxies look like now?

Joel Bennet

It's true that we only see galaxies as they used to be, because the light emitted from them takes a long time to get to us - millions if not billions of years, in fact. So we can only speculate on what they really look like now. The most-distant galaxies are also the youngest, so technically they are galactic babies as we see them.

Given our understanding of how galaxies grow and evolve, it's thought that they might now look like the galaxies that are closest to us, but unfortunately we just don't know for sure and we're unable to get a good handle on how these distant galaxies might have evolved into the ones we see nearby. We can, however, get some hints by studying the galaxies at intermediate distances from us. **GL**

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

ASTRONOMY

What is an occultation?

Gary Williams

An occultation is an astronomical event that happens when one celestial object is hidden by another one. For example, you might have heard of the occultation of Saturn by the Moon. What's happening here is that the ringed planet has just appeared from the limb of our satellite, given the observer's position on Earth.

Astronomers enjoy an occultation just as much as any other astronomical event and pretty much any body in space can occult another. From Earth, stars can occult planets and in extremely rare cases, one planet will occult another - however, this hasn't occurred since January 1818. The next event of this kind, which will be between Venus and Jupiter, should be in November 2065. **GL**

Venus pops out from behind the Moon in an occultation

Massive stars explode on their own when they run out of fuel to burn

DEEP SPACE

What happens when a star's fuel runs out?

Tim Baldwin

When stars run out of fuel they begin to collapse rapidly under their own weight. Some stars that are large enough naturally end their lives by exploding in a supernova.

Throughout their lives, stars are fighting against the crushing force of their own gravity. Inside, nuclear reactions fuse together smaller elements, like hydrogen, to create bigger ones and release energy. Stars must burn through fuel and release energy to prevent them from collapsing in on themselves, but this cannot go on forever. Eventually the star will run out of its essential fuel entirely, resulting in its explosive end.

The compression of a star many times larger than our Sun can be so much that a rebounding shockwave is created. This can cause a final expansion that releases the layers of a star in a supernova. **ZB**

Quick-fire questions

@spaceanswers

Who were the last men on the Moon?

Eugene Cernan and Jack Schmitt of NASA's Apollo 17 mission were the last men on the Moon when they landed on its surface in 1972.

What is the Van Allen radiation belt?

The Van Allen radiation belt surrounds the Earth and is comprised of subatomic particles, electrons and protons, which are held captive by our planet's magnetic field.

What does it mean when something is blueshifted?

When a galaxy, for instance, moves towards us, it's blueshifted. When it throws out its light, this light get squashed to the blue end of the spectrum.

What's the brightest star in the night sky?

With a magnitude of -1.46, Sirius is the brightest star in the night sky. While perceived as a single star, Sirius is a multiple system of stars.

Where are NASA headquarters based?

The National Aeronautics and Space Administration is based in Washington, D.C., USA.

What would happen to the planets if our Sun suddenly disappeared?

Due to its great gravitational influence, the planets in the Solar System would fly off in a straight line through space rather than the elliptical orbits they're in now.

How did our Moon first get its name?

Our satellite has been known since prehistoric times, so tracing where its name originates from is difficult. Lunar, however, comes from the Roman word Luna.

Quick-fire questions

@spaceanswers

What's the second biggest planet in the Solar System?

At only about 1.2 times smaller than the king of the Solar System, Jupiter, Saturn is the second largest planet.

What made the black hole at the centre of the Milky Way?

Since we're unsure of what came first - the black hole or the galaxy itself - there's no concrete answer. We are continuing to study supermassive black holes found at the centre of galaxies, so maybe one day we'll find out!

What is currently the longest-serving spacecraft in the world?

The Russian's Soyuz spacecraft are the longest serving. They were originally designed for the Soviet space programme.

How many Space Shuttles were built?

Five Space Shuttles were built - Columbia, Challenger, Discovery, Atlantis, Endeavour.

What does the word Mir stand for?

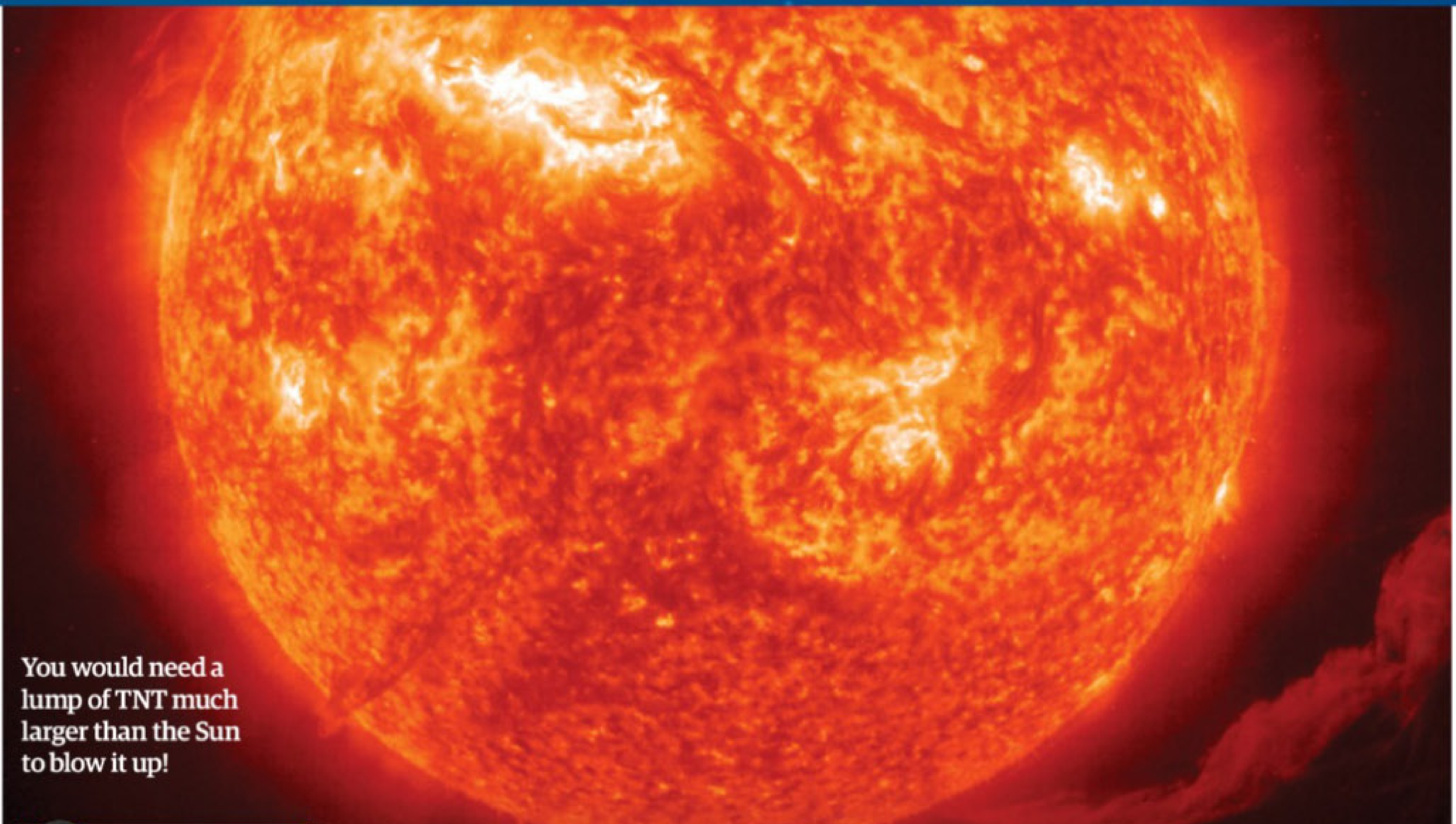
This isn't an acronym, but stands for peace or world in Russian.

Where exactly does space begin?

From our position on Earth, it is said that space begins at an altitude of 100 kilometres (62 miles) in altitude. We call this the Kármán line.

How far into the past will we be able to see with the James Webb Space Telescope (JWST)?

Using its array of instruments, the JWST will be able to see to a point just hundreds of millions of years after the universe began.



You would need a lump of TNT much larger than the Sun to blow it up!

SOLAR SYSTEM

How much TNT would you need to blow up the Sun?

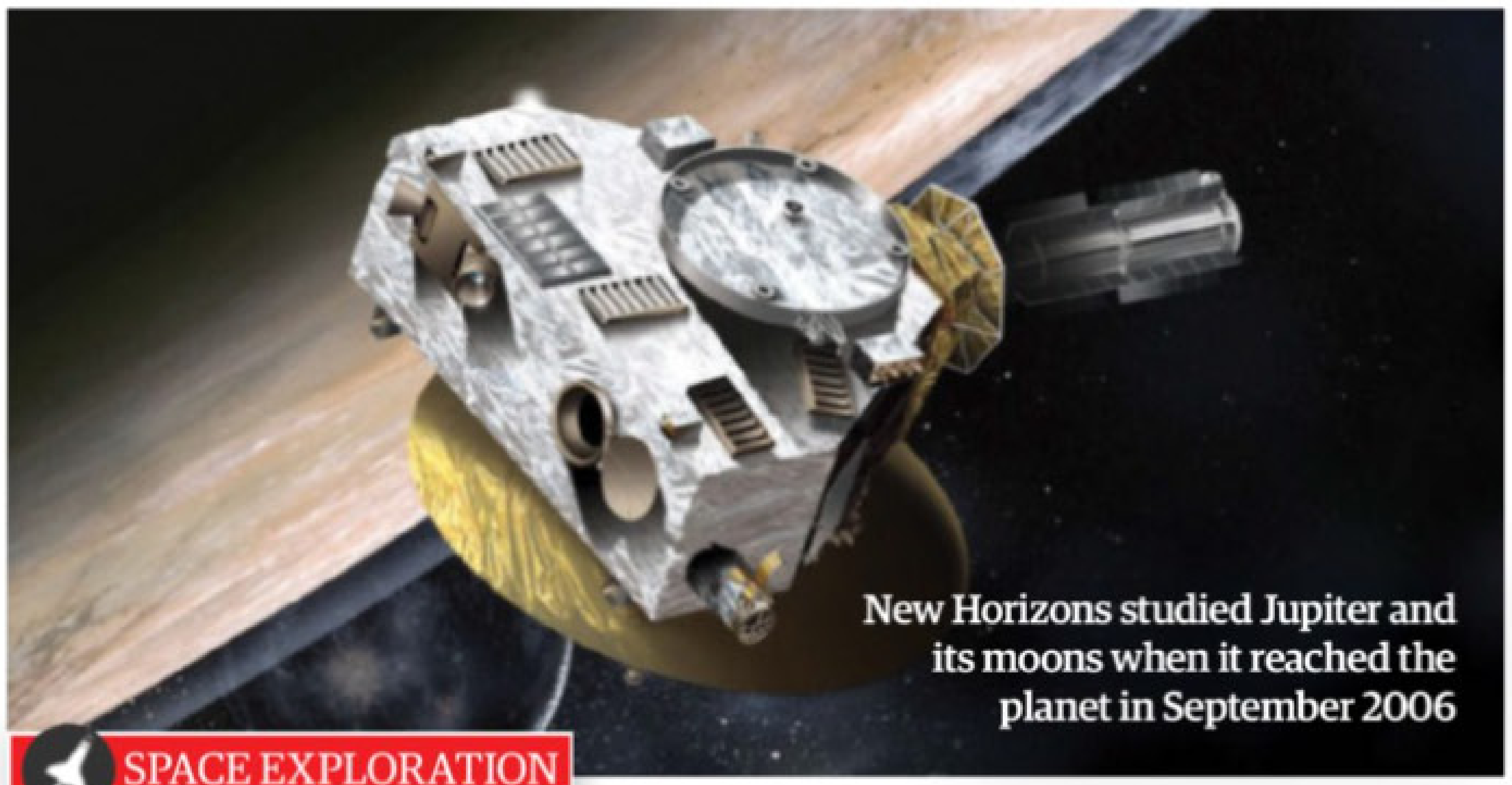
Chris Richardson

To completely vaporise the Sun you need to overcome something called its gravitational binding energy. To do that would require a lump of TNT larger than the Sun, roughly 6 x 10^{34} tons (60 billion, trillion, trillion tons!).

Overcoming the gravitational binding energy would destroy the Sun, as this is the energy required to blow all its bits to an infinite distance away.

Obviously, you wouldn't need nearly as much of an energy release to cause problems for us here on Earth: the Sun regularly shrugs off solar flares with little to no affect on itself, but some coronal mass ejections that follow can cause havoc with satellites and power grids on Earth.

These can have an energy output equivalent to 1.6 x 10^{17} (160,000 trillion) tons of TNT. **ZB**



New Horizons studied Jupiter and its moons when it reached the planet in September 2006

SPACE EXPLORATION

Did New Horizons study Jupiter during its flyby?

Lizzie Wilson

New Horizons, currently making its way to Pluto, took its very first photographs of Jupiter in 2006. At the time the spacecraft was around 291 million kilometres (181 million miles) away.

It wasn't until January 2007 that New Horizons began to explore Jupiter and its moons. Since the gas giant is an ever-changing scientific target, the spacecraft observed the planet's atmospheric conditions and analysed the structure and composition of its clouds.

Lightning strikes raging in the polar regions, as well as other violent storm activity, were observed and measured. In particular, New Horizons got up close to and imaged Jupiter's Little Red Spot, which spans up to 70 per cent of Earth's diameter, for the very first time. **GL**

Plössl eyepieces are ideal for a variety of astronomical observations

ASTRONOMY

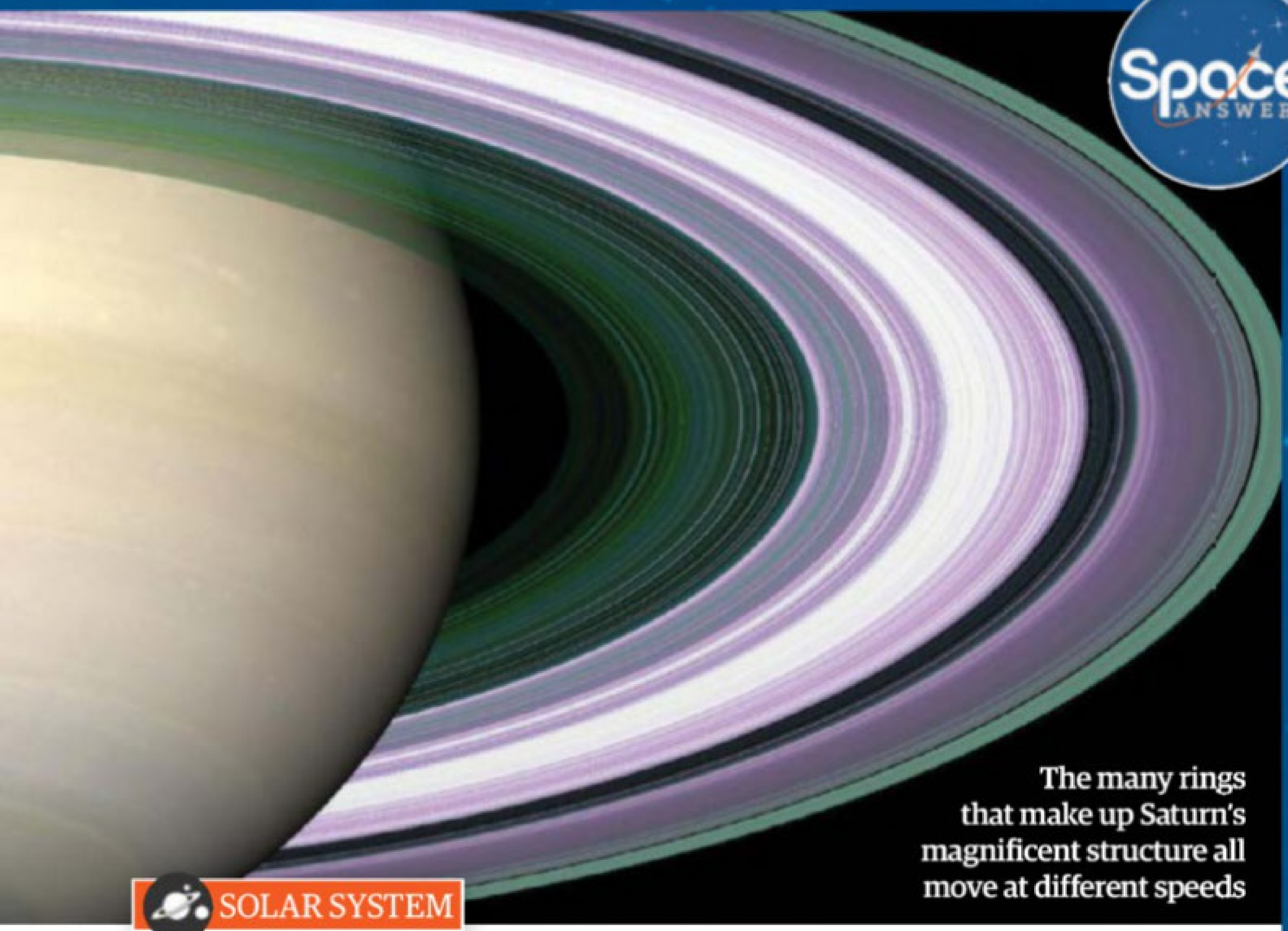
Why are some eyepieces given the name Plössl?

James Bell

Plössl eyepieces are named after their designer Georg Simon Plössl, who invented them in 1860. This eyepiece type is ideal for a variety of observational purposes employed in astronomy, such as planetary and deep-sky viewing. This is because they have a wide field and, as a result, they are a very popular choice among astronomers. They are made from very expensive glass and prevent internal reflections that can ruin nighttime observations.

However, the shorter the focal length of an eyepiece (usually less than 10mm), the poorer the eye relief and the more uncomfortable it is for people wearing glasses. **GL**

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com



The many rings that make up Saturn's magnificent structure all move at different speeds

SOLAR SYSTEM

Do Saturn's rings move at different speeds?

Fern Berger

Saturn's rings do actually move at different speeds to one another. The rings are generally constructed of rock, dust and ice and orbit the planet. As a result they follow standard orbital mechanics, so there's nothing special about the rings that enables them to ignore this. This means they follow a standard relationship where their orbital period is proportional to the distance from the centre of mass (the planet, in this case).

To stay in a stable orbit around Saturn, the inner rings are moving much faster that the outer - the same way the satellites around Earth have variable velocities depending on their positions. This difference in velocity actually helps to power some of the more-complex behaviour and interactions seen in Saturn's rings. **JB**

Despite the artist's impressions that you may have seen, the Big Bang wasn't an explosion

DEEP SPACE

Was the Big Bang an actual explosion?

Harry McDonald

Despite its name, the Big Bang wasn't a tremendous explosion. According to our current theory, the universe started out much hotter and denser than it is today, before expanding and cooling over time. It initially existed as a single point of infinite temperature and density.

An explosion implies that the universe began from a centre point and quickly moved outward into space - of course, this isn't exactly how the Big Bang played out. However, scientists can understand why many refer to it as great explosion. The universe doubled in size every tiny fraction of a second, so it's quite easy to make the connection even though the dynamics are different compared with a standard outburst. **GL**

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Next Issue

ROSETTA: COMET CHASER

The ambitious mission that aims to land on a speeding comet

ASTRONOMY BEGINNER'S GUIDE

Everything you need to kick-start a new hobby in stargazer

BIGGEST GALAXY IN SPACE

All About IC1101, a monster galaxy million light years wide

EXPLORING PLUTO

New Horizons has its rendez-vous with Pluto coming up - what can we expect to see?

+

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GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

In this issue...

82 **Comet hunting**
How to locate and claim your very own comet

86 **What's in the sky?**
Find the most-spectacular nighttime objects

88 **Me and my telescope**
Readers showcase their best astrophotography images

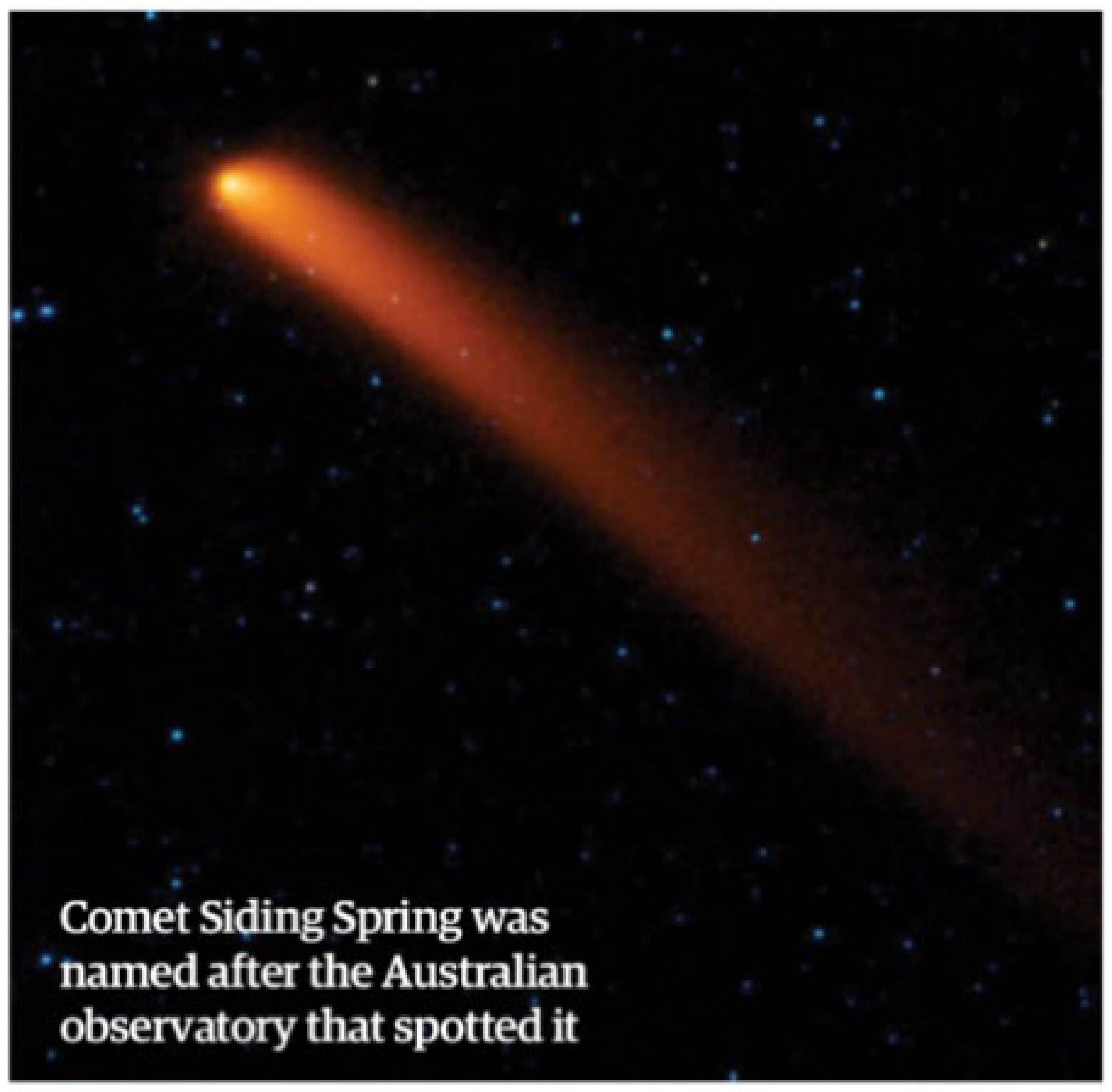
94 **Astronomy gear reviews**
The latest essential astronomy kit and telescopes reviewed

Comet hunting

Want to find your very own comet? Follow our guide and you could make a rare discovery

Comets have fascinated and frightened humans in equal measure for thousands of years. They were previously seen as harbingers of doom, signalling oncoming disaster, but today they are the subject of intense scientific scrutiny. We now know that they are icy relics from the formation of our Solar System, spending most of their time far away from the Sun, past the orbit of Pluto even. Occasionally they plummet in towards the inner Solar System and many astronomers believe that comets impacting the Earth were responsible for delivering much of the water our planet has today. It's possible they even deposited complex organic compounds, which could have acted as the building blocks for life itself. What's certain is that they are responsible for the spectacular meteor showers that we are treated to every year – as the Earth passes through a trail of debris left behind by a comet, that material burns up in the atmosphere to produce shooting stars.

The famous Halley's comet visits Earth only once every 80 years or so



Comet Siding Spring was named after the Australian observatory that spotted it

Hyakutake had a 17,000-year orbit before the gas giant planets perturbed it in 1996, changing it to 70,000 years!

"There are still plenty of undiscovered comets out there waiting to be found"

The most famous of these repeat visitors is Halley's comet, which is also responsible for the Orionid meteor shower. An orbiting ball of ice and dust, it has been recorded by humans since at least 240 BC and even appears in the famous Bayeux tapestry. The last time it came by was in 1986, when the European Space Agency dispatched the Giotto probe to study its nucleus. It won't return again until 2061. However, there are still plenty of undiscovered comets out there waiting to be found and many of them are found by amateur astronomers with affordable telescopes.

One such comet, Lovejoy, is among the most famous and spectacular comets of recent years. It streaked past the Earth back in 2011 and was discovered by Australian amateur astronomer Terry Lovejoy from his home in Queensland. He was using an amateur telescope costing around £750 ($1,250). Nevertheless, his find was later photographed by NASA's Solar and Heliospheric Observatory (SOHO) as it grazed past the Sun, as well as by the crew of the International Space Station. So, just how can you get in on the comet-hunting act too?

Head over to page 95 to check out our reviews of two high-end astrophotography imagers

Equipment

Start off with the right kit

The more light you can grasp, the better, so it's recommended you use a minimum of a 4" refractor. Reflectors can also be used, and it's even possible to hunt down comets with nothing more than a pair of binoculars. Legendary British amateur astronomer George Alcock was able to discover five comets this way – he meticulously memorised the positions of 30,000 stars in order to be able to realise when an imposter had arrived.

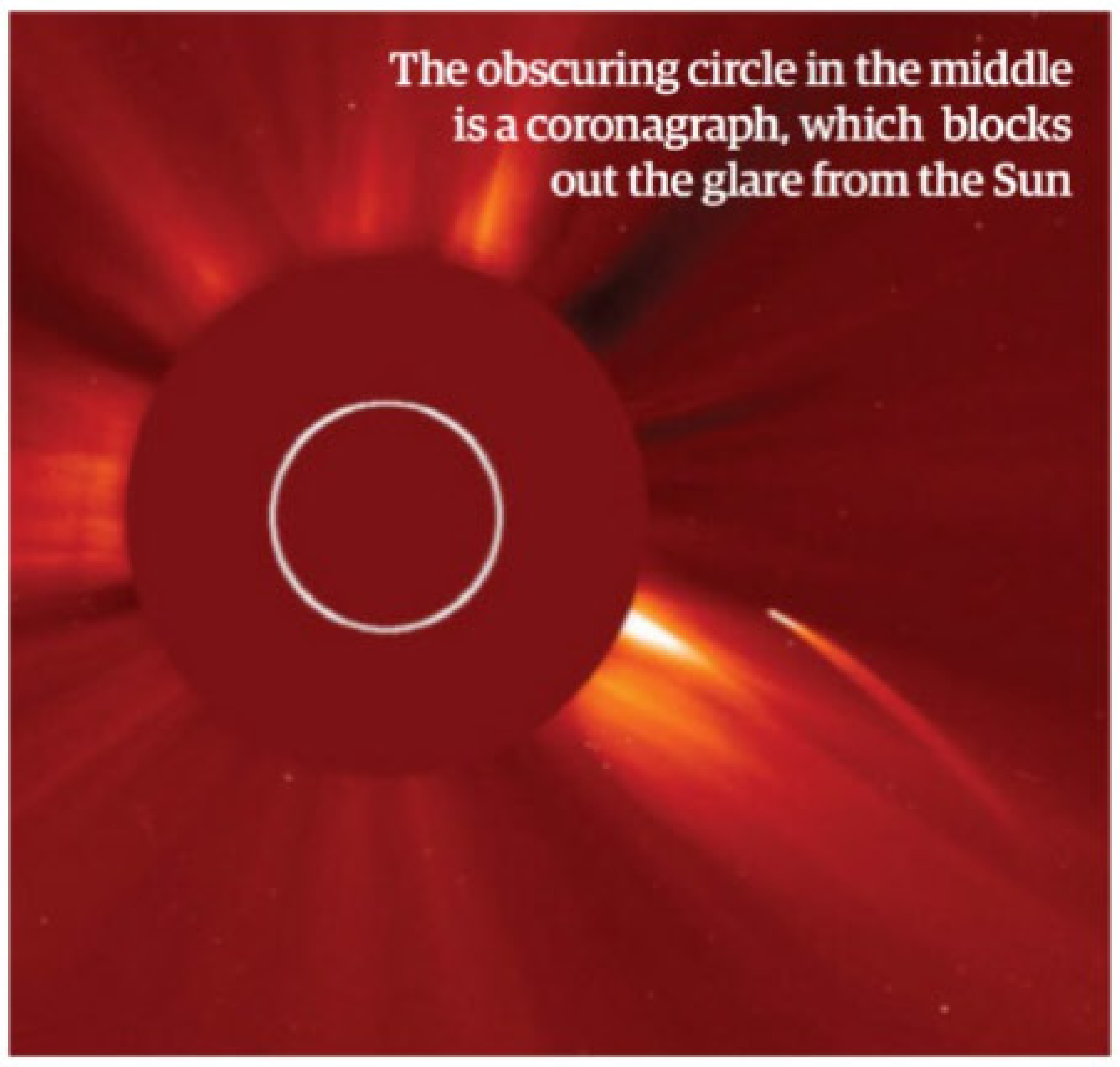
It pays to attach a CCD camera to your telescope, as it enables you to use image-processing software to get the most out of your observations. There are also free pieces of software – including Find_Orb and Astrometrica – which are invaluable to the comet hunter. They can take your observation data and compute the likely orbit of the comet, which is crucial if you're to submit your find for consideration by the Minor Planet Center.

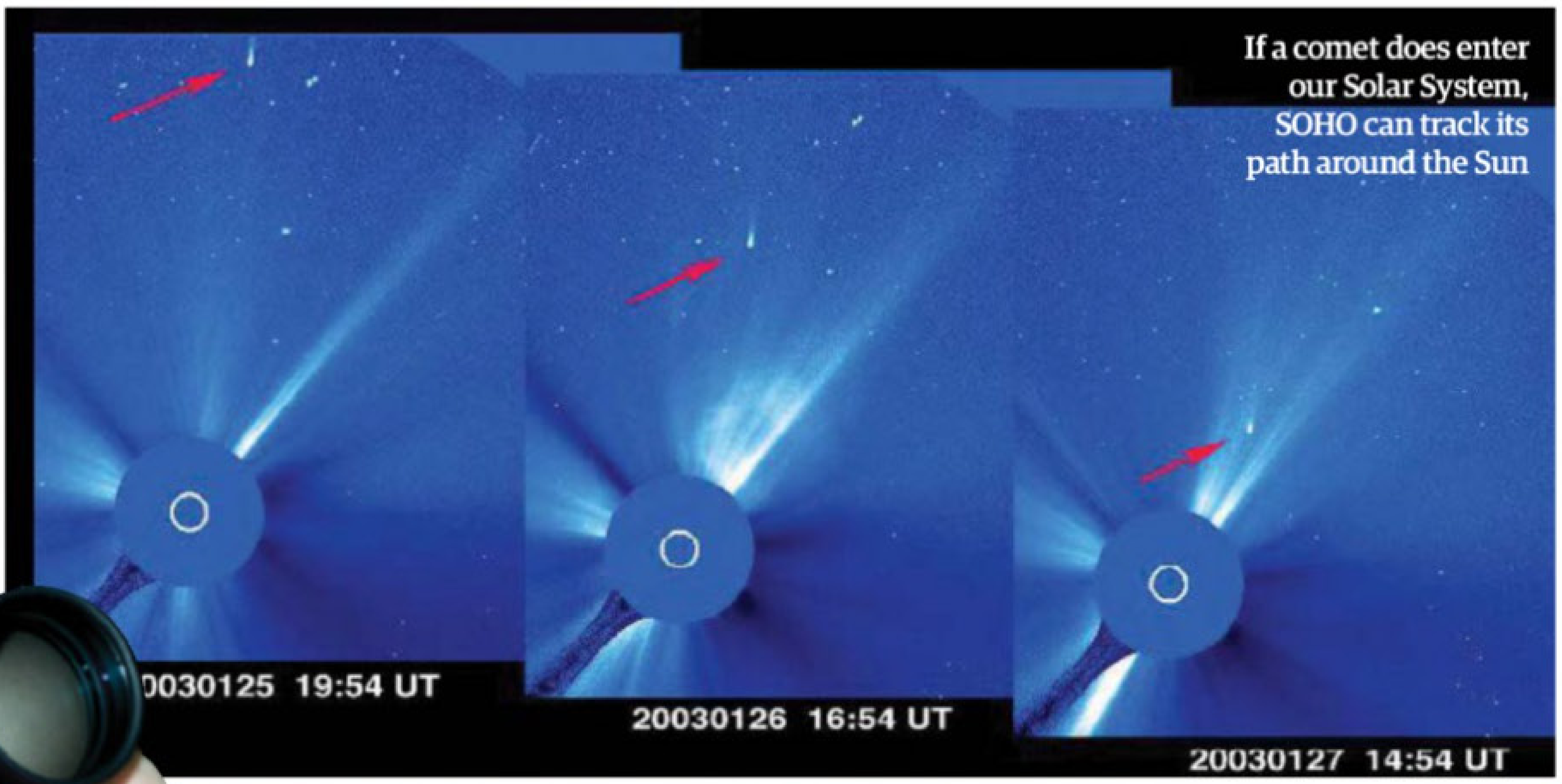
First you need to get to know the sky. Comets become visible when they reach approximately the same distance from us as Jupiter. So if you know exactly where everything should be, it's easier to tell when a new object suddenly appears. The best place to look is along the ecliptic plane – the area of the sky traced out by the 12 famous signs of the zodiac. This area is roughly aligned with the flat disc of our Solar System, so you are more likely to find comets close to this region. Another simple tip is to avoid nights with a bright or full Moon.

Although some amateurs have discovered comets using just binoculars, it's best to use a medium-sized telescope. You're after a wide field of view so that you can sweep around large parts of the sky. This means selecting a wide eyepiece to give you low magnification. Many comet hunters also invest in a suitable CCD camera that can be attached to their telescope. By taking long-exposure photographs, you should be able to pick up objects that it would be hard to spot with your eyes alone. It also means you can record your find and use computer software to help you submit it to the proper authorities.

What you're looking for is something fuzzy that doesn't seem to belong. Be careful, however, as it is possible to be fooled by other fuzzy objects that are not comets. In the late 18th century, renowned French comet hunter Charles Messier was faced with the same problem. He was continually stumbling across potential comets, only to find they were distant galaxies, star clusters or nebulae instead. He assembled a list of these objects to help other comet hunters. This Messier catalogue is still widely used today by professional and amateur astronomers alike. Some famous night-sky objects appear in the list, including the Orion nebula (M42) and the Pleiades (M45). His list is an invaluable tool if you don't want to be led up the garden path.

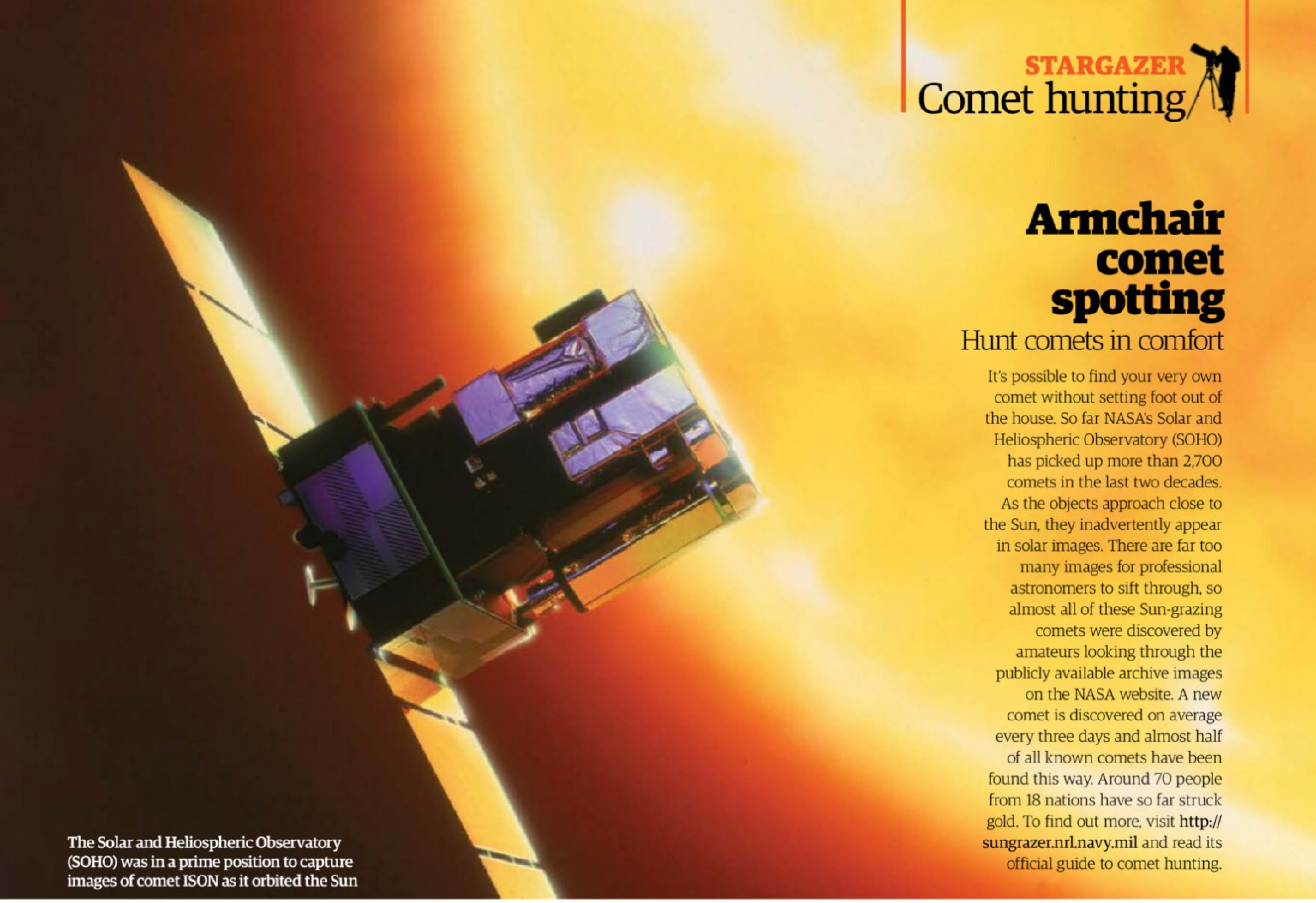
Another key property to look out for is movement. Objects outside our Solar System – like stars and nebulae – will remain in a fixed location relative to the constellations. These constellations will also move throughout the night as the Earth rotates, but everything beyond the Solar System will appear to move along with them at the same rate. Objects close


The obscuring circle in the middle is a coronagraph, which blocks out the glare from the Sun



If a comet does enter our Solar System, SOHO can track its path around the Sun

Comet Kohoutek was supposed to be the 'comet of the century', but it broke up as it approached the Sun



The Solar and Heliospheric Observatory (SOHO) was in a prime position to capture images of comet ISON as it orbited the Sun

Armchair comet spotting

Hunt comets in comfort

It's possible to find your very own comet without setting foot out of the house. So far NASA's Solar and Heliospheric Observatory (SOHO) has picked up more than 2,700 comets in the last two decades. As the objects approach close to the Sun, they inadvertently appear in solar images. There are far too many images for professional astronomers to sift through, so almost all of these Sun-grazing comets were discovered by amateurs looking through the publicly available archive images on the NASA website. A new comet is discovered on average every three days and almost half of all known comets have been found this way. Around 70 people from 18 nations have so far struck gold. To find out more, visit **http://sungrazer.nrl.navy.mil** and read its official guide to comet hunting.

> "Objects close to home can move at high speeds - comets can reach hundreds of miles per second"

to home can move at high speeds - comets can reach hundreds of miles per second.

If you're lucky enough to spot a brand-new comet, and it gets ratified by the Minor Planet Center, then you get to name the comet. So, just how hard is it to learn the skills required to be a good comet hunter? In truth, it's just like learning to play the violin - you can play a tune in a few weeks, but it takes years to become an expert. More information on the technical aspects of comet hunting can be found by reading the *Minor Planet Center's Guide to Minor Body Astrometry*, which can be easily found at most bookstores, as well as online stores.

So, comet hunting takes quite a bit of effort, and more than a little patience, but the rewards are huge. You could be the first human to set eyes on an ancient lump of ice that has been tumbling unobserved around the Solar System for billions of years. What's more, that comet could forever bear your name as its discoverer. ●

What to do when you think you've found a comet

How to claim your find

Any potential discoveries should be reported to the International Astronomical Union's Minor Planet Center. This is currently based at the Smithsonian Astrophysical Observatory in Massachusetts, U.S.A.

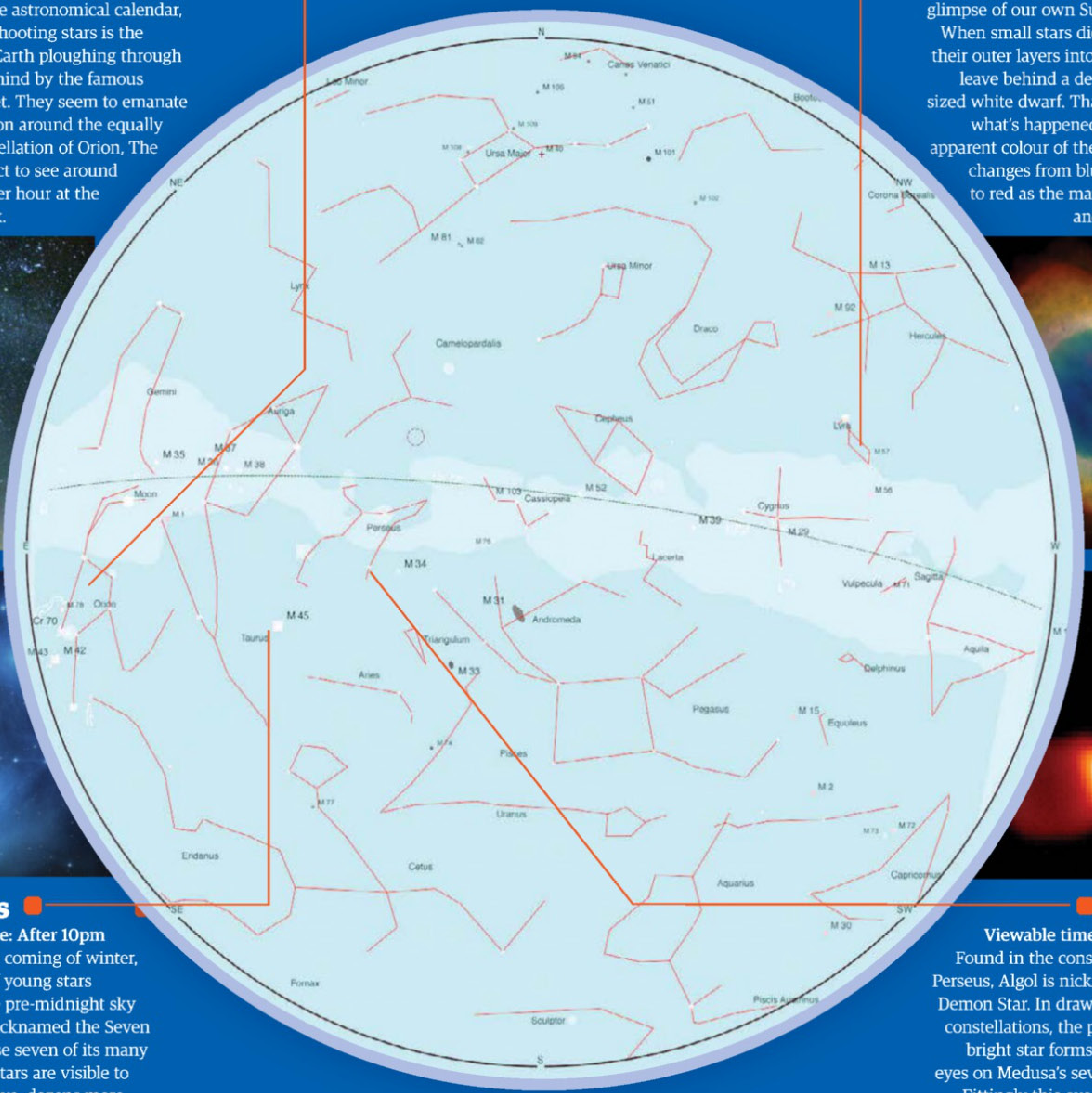
The Center's submissions guidelines can be found at **www.minorplanetcenter.net**. It requires the details of the potential comet in a specific format, which can be created by using computer software such as Astrometrica. The Center's computers then calculate if the object is indeed new. If it is successfully validated, then it appears on their Near Earth Object confirmation page and you get naming rights!

What's in the sky?

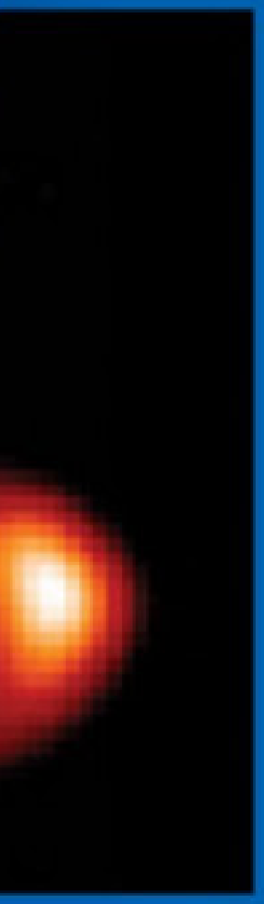
All seasons change for both hemispheres, as dark skies lengthen in the north and the south creeps towards a long summer

Orionids

Viewable time: From 2 October (Peak 20-22 Oct) after midnight
One of the more-notable meteor showers in the astronomical calendar, this bevy of shooting stars is the result of the Earth ploughing through debris left behind by the famous Halley's comet. They seem to emanate from the region around the equally famous constellation of Orion, The Hunter. Expect to see around 20 meteors per hour at the shower's peak.



Northern Hemisphere



Ring nebula (M57)

Viewable time: Before 2am
This planetary nebula in the constellation Lyra provides a glimpse of our own Sun's future. When small stars die they puff their outer layers into space and leave behind a dense, Earth-sized white dwarf. That's exactly what's happened here. The apparent colour of the gas shells changes from blue through to red as the material cools and expands.

Pleiades

Viewable time: After 10pm
Heralding the coming of winter, this cluster of young stars returns to the pre-midnight sky in October. Nicknamed the Seven Sisters because seven of its many hundreds of stars are visible to the unaided eye, dozens more can be glimpsed with a pair of binoculars. At just 100 million years old, they are some of the youngest stars visible from Earth.

Algol

Viewable time: All night
Found in the constellation of Perseus, Algol is nicknamed the Demon Star. In drawings of the constellations, the particularly bright star forms one of the eyes on Medusa's severed head. Fittingly this eye appears to wink roughly every two days and 21 hours due to another star passing in front of it. Algol is also a so-called eclipsing binary.

Canopus

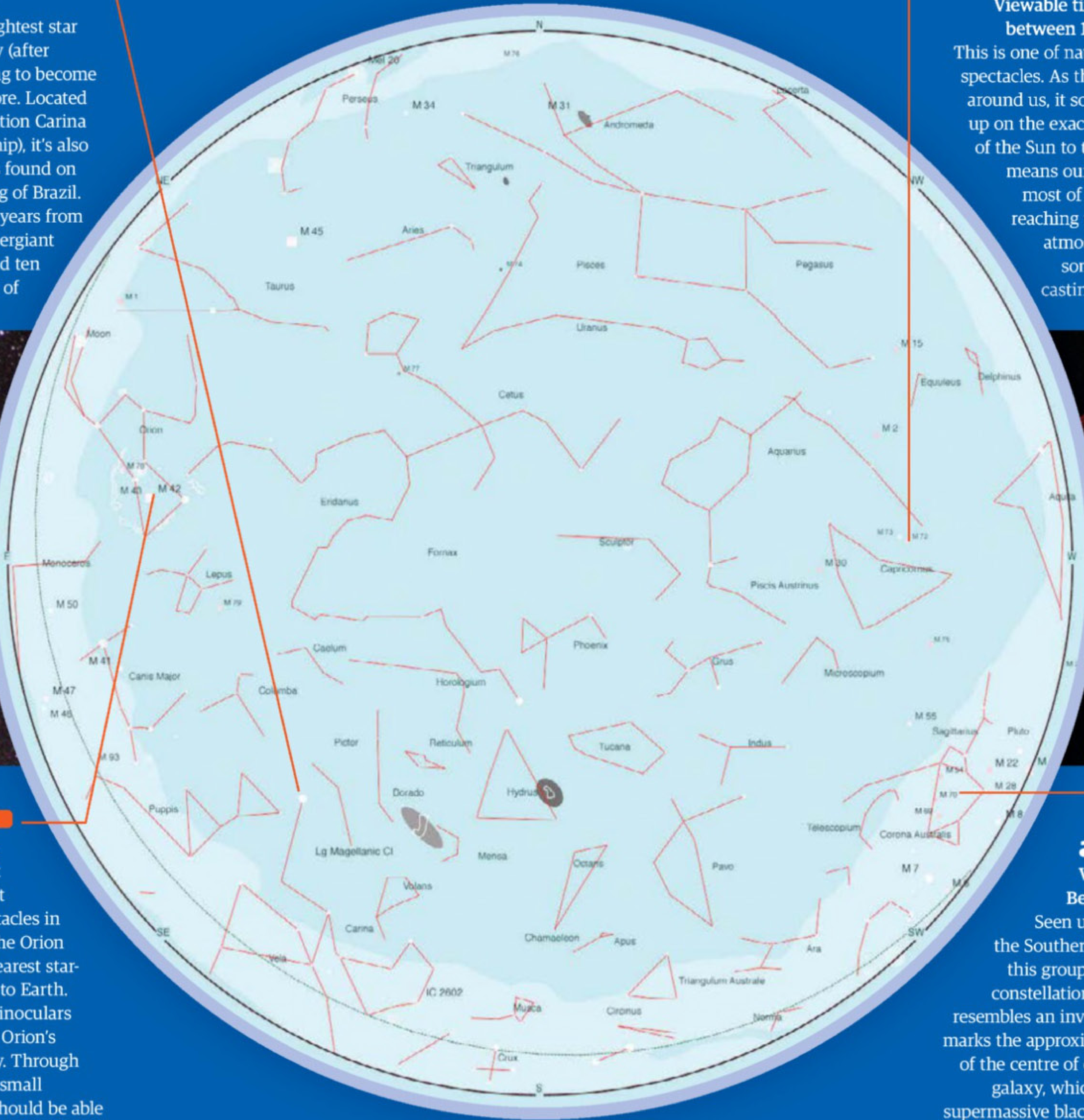
Viewable time: Around 9pm onwards

The second-brightest star in the night sky (after Sirius) is starting to become visible once more. Located in the constellation Carina (the keel of a ship), it's also one of the stars found on the national flag of Brazil. Lying 310 light years from us, this is a supergiant star with around ten times the mass of our Sun.

Orion nebula

Viewable time: After midnight

One of the most accessible spectacles in the night sky, the Orion nebula is the nearest star-forming region to Earth. Even without binoculars this area under Orion's Belt looks fuzzy. Through binoculars or a small telescope you should be able to make out the four stars of the Trapezium Cluster, which lies close to its heart.



Southern Hemisphere

Total Lunar Eclipse

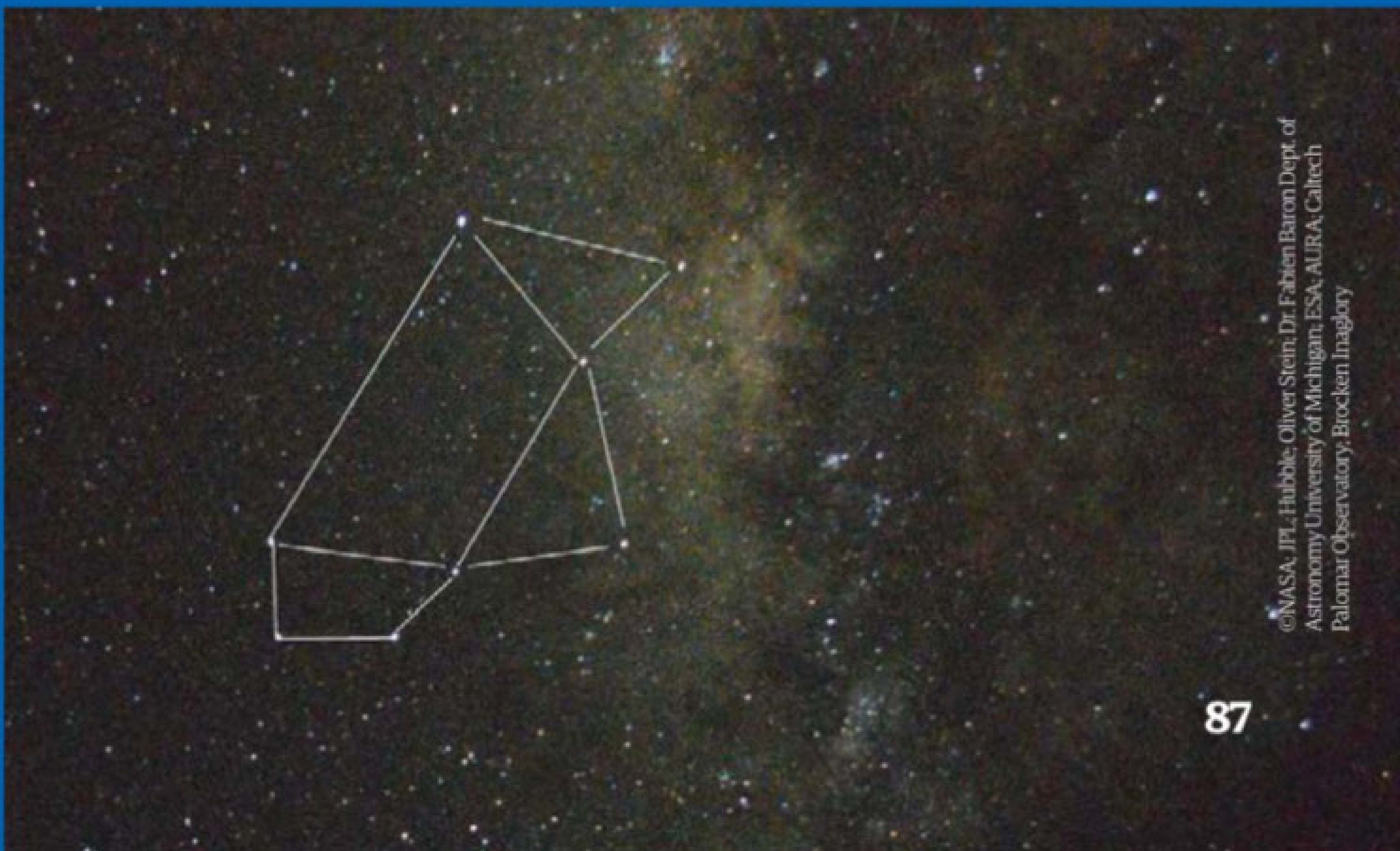
Viewable time: 8 October between 10:54-10:55 UT

This is one of nature's grandest spectacles. As the Moon orbits around us, it sometimes ends up on the exact opposite side of the Sun to the Earth. This means our planet blocks most of the Sun's light reaching the Moon. Our atmosphere refracts some of the light, casting the Moon in shade of red.

The Teapot asterism

Viewable time: Before midnight

Seen upside-down in the Southern Hemisphere, this group of stars in the constellation of Sagittarius resembles an inverted teapot. It marks the approximate direction of the centre of our Milky Way galaxy, which is home to a supermassive black hole. It takes the Sun around 230 million years to complete just one orbit of the four-million-solar-mass monster.



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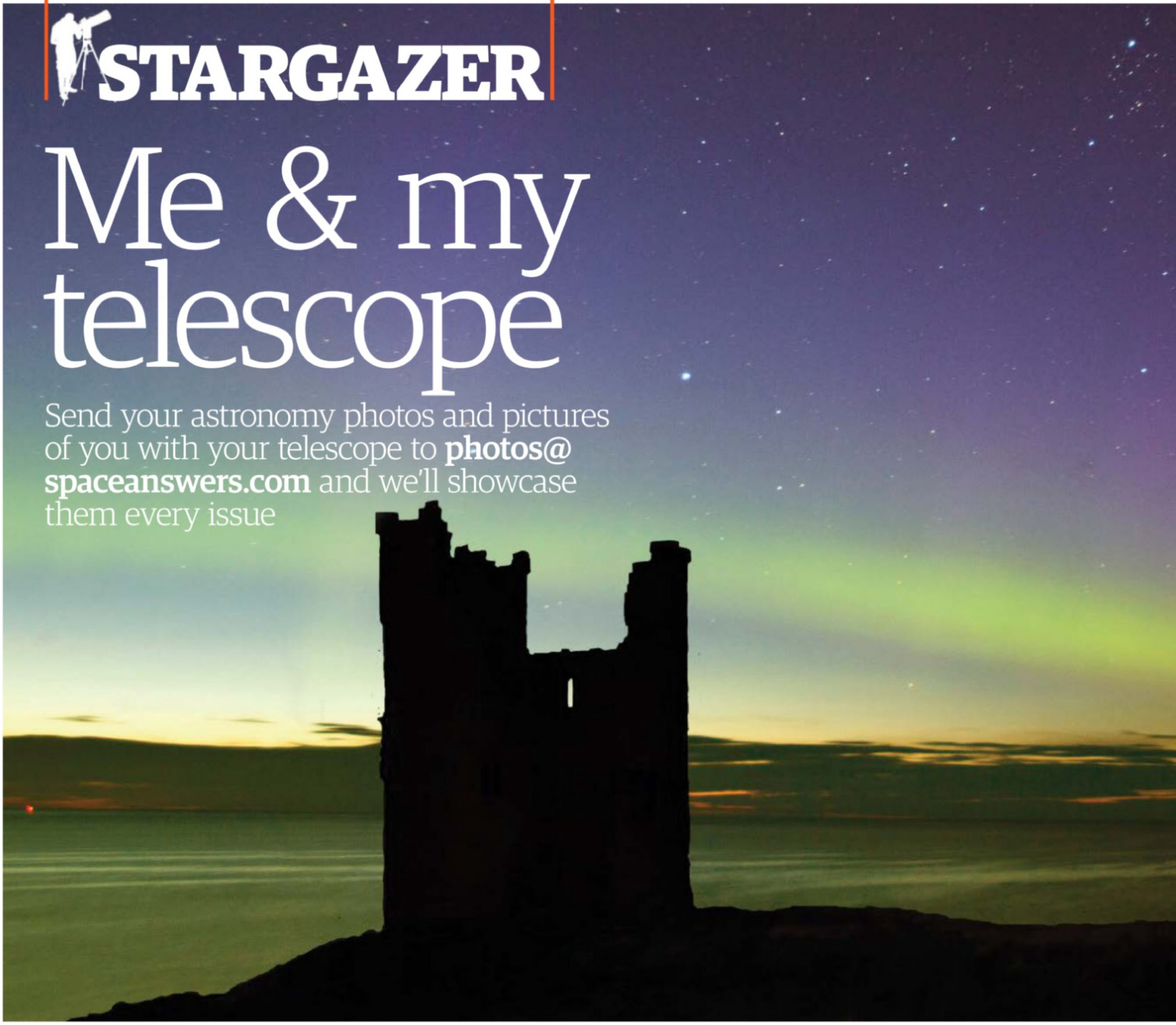
Me & my telescope

Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue

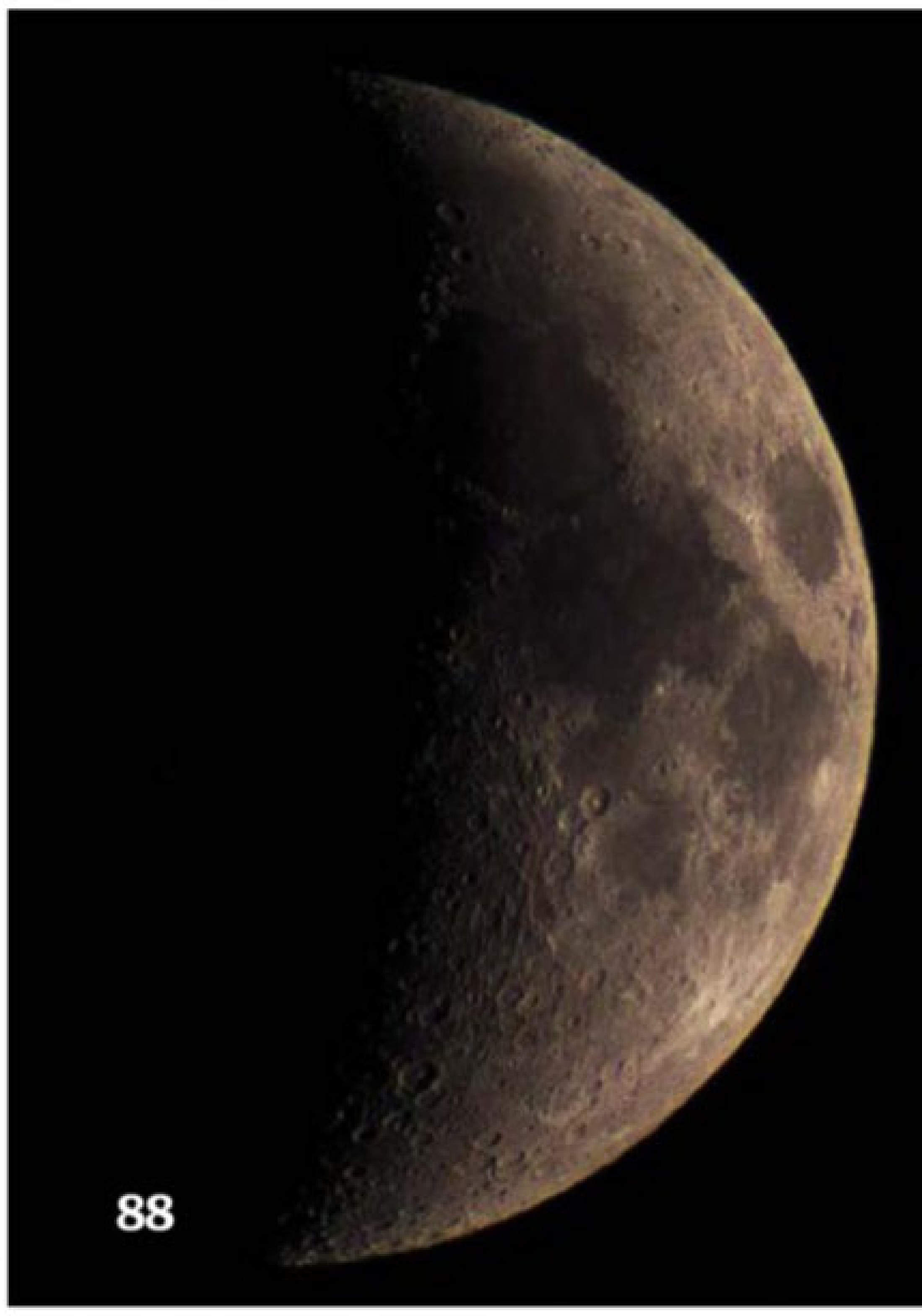


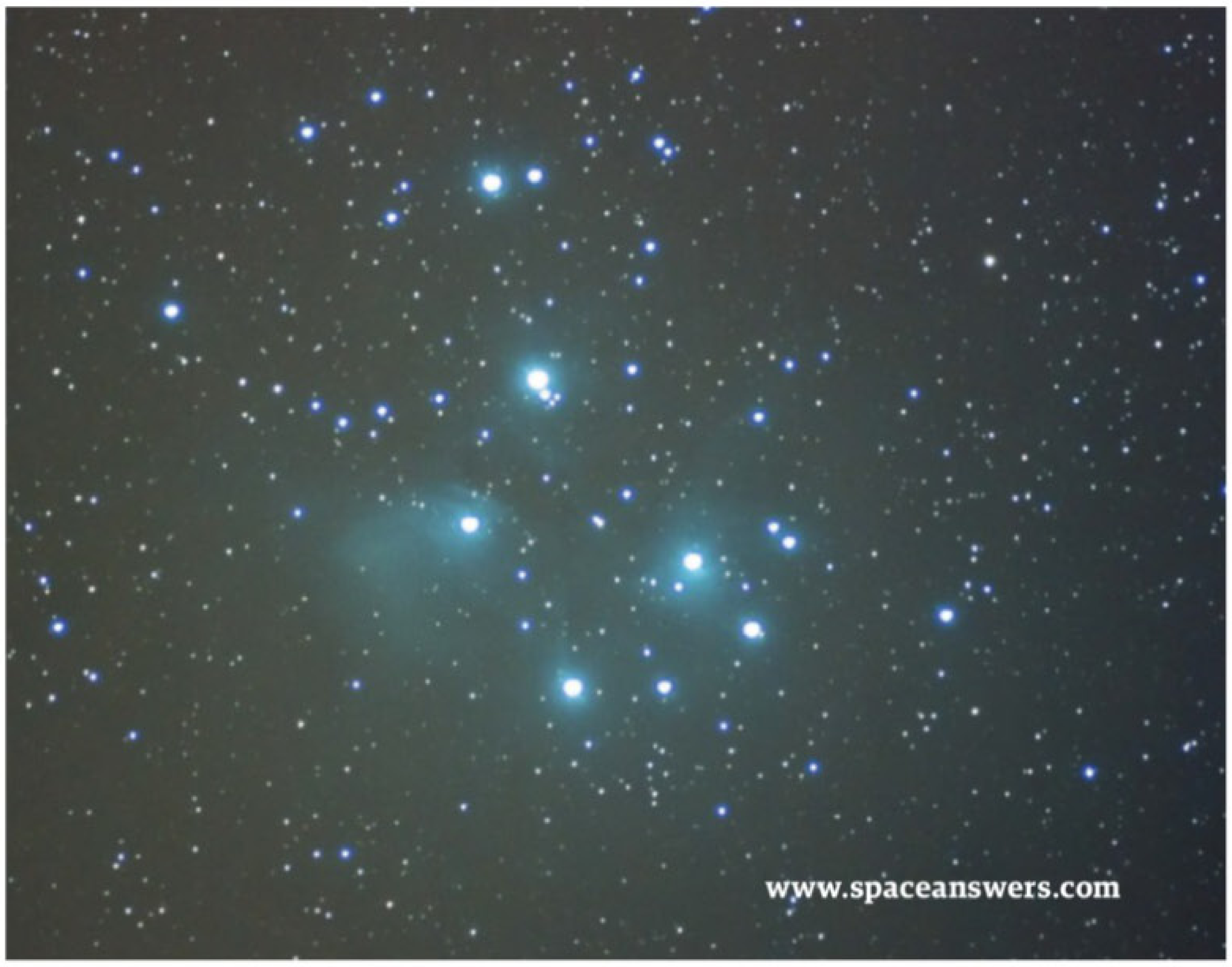
Johnny Rowe

Belpen, Derbyshire
Telescope: Sky-Watcher ST80, Celestron AstroMaster 130 & Celestron 80 GTL

"I'm proud of these images as they were all taken with relatively cheap equipment that some astrophotographers might say isn't good enough for deep-space images...

"I took all of my images using my Canon 1100D camera from my back garden. [I] stacked my frames in DeepSkyStacker and then processed in Photoshop."





Lee Jennings

Newbiggin, Northumberland

Telescope: N/A

"I have been interested in astronomy since I was a small child and was introduced to it by my granddad who, at the time, had a small pair of binoculars.

I was amazed when I first saw craters on the Moon and astounded even further when I got my first real telescope and my first view of Saturn's rings. Recently I caught the Aurora in Creswell, Northumberland using my Canon 5D."

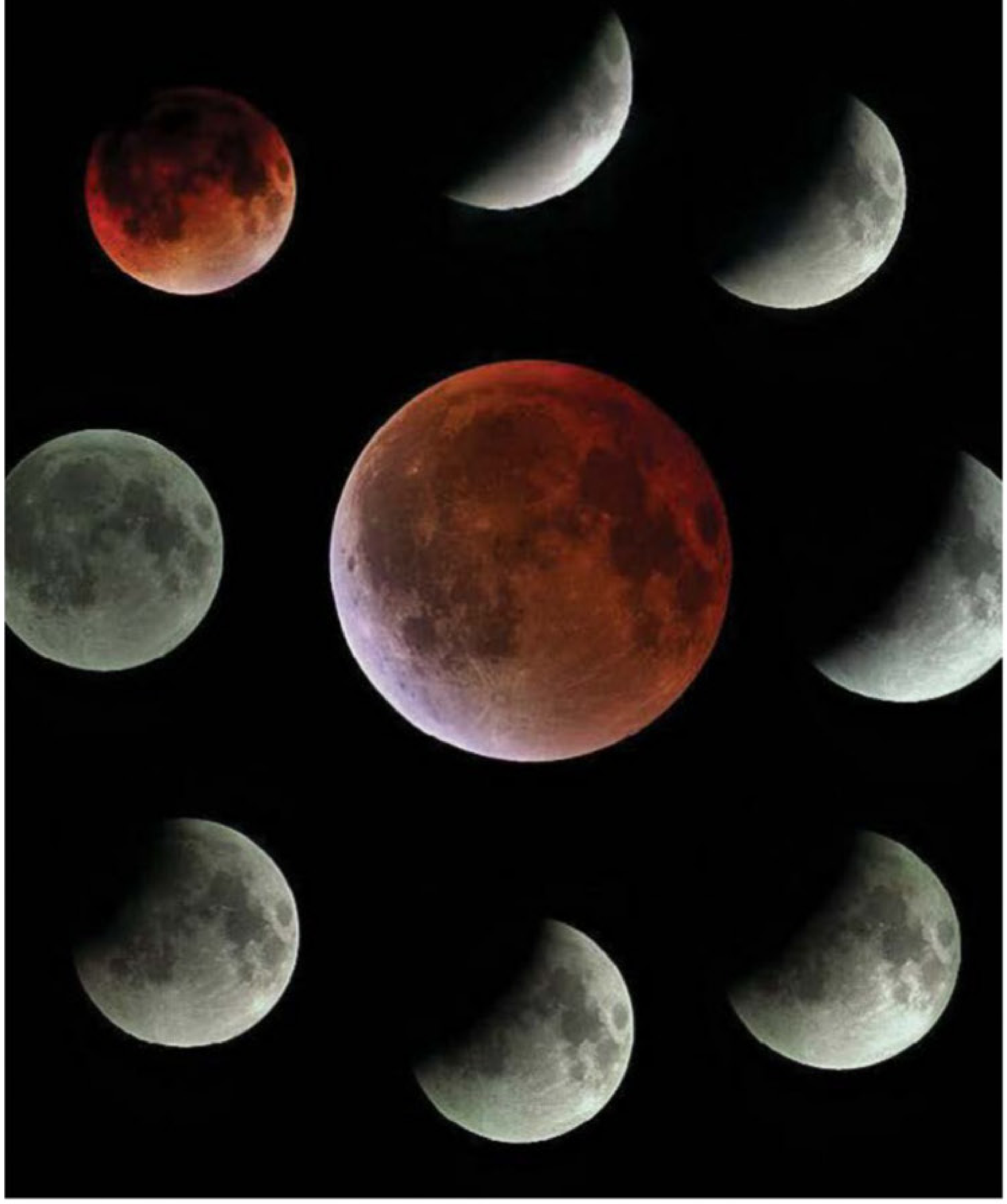
Cristo Sanchez

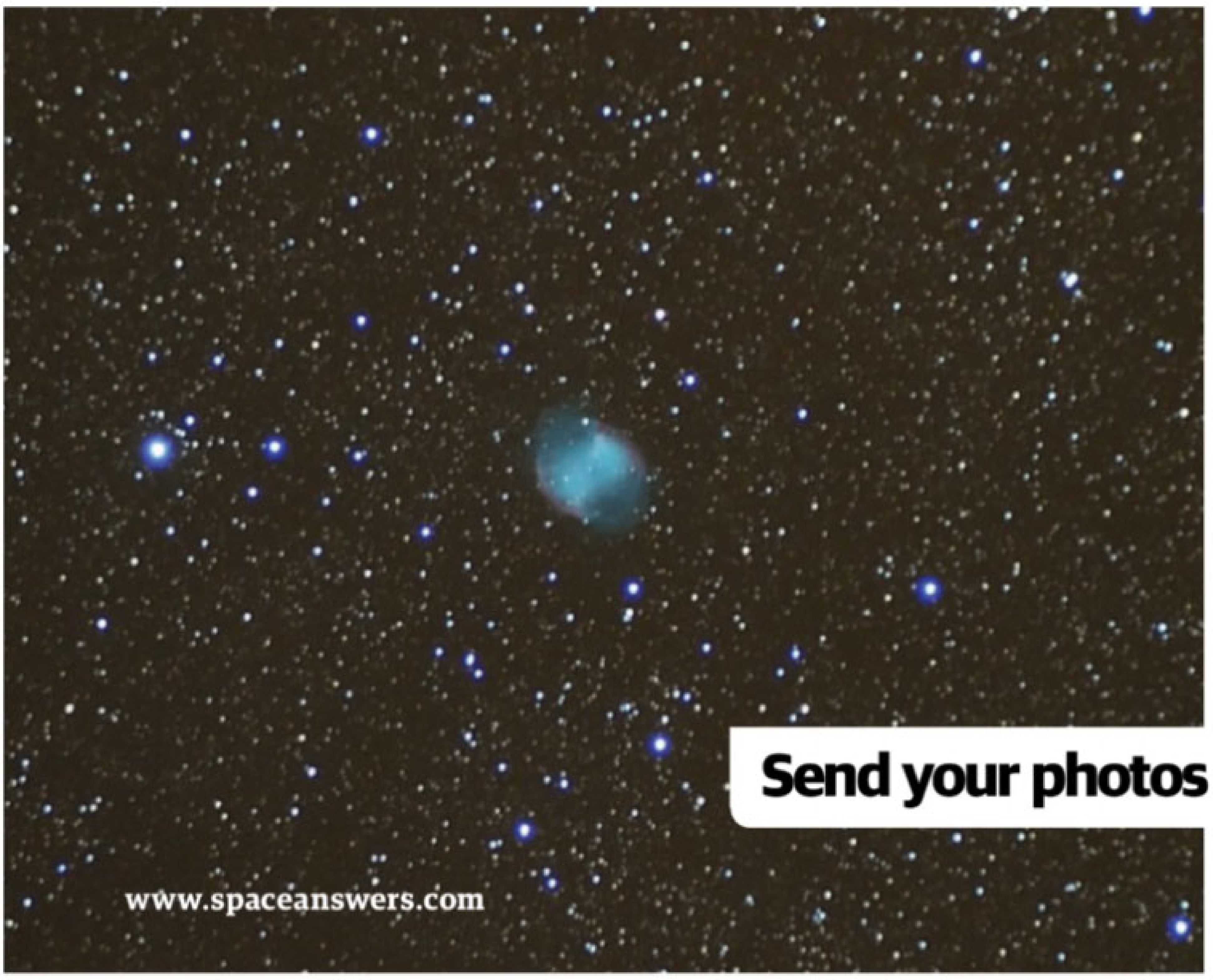
Yantis, Texas

Telescope: Orion AstroView 6 EQ reflector

"My passion for astronomy began at the young age of 12. From that point on, and now at the age of 16, I have studied, observed and photographically captured the cosmos.

"Shooting astrophotography is always an exciting thing to do when the skies are clear. Whether it's imaging planets, Messier objects or the Moon, it's always worth the long hours of capturing and processing your images. In the end, you get a great feeling seeing the final result and being able to share it with others in the astronomical community as well as social media."





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Stargazing stories

Email the story of how you got into astronomy to **photos@spaceanswers.com** for a chance to feature in **All About Space**

Damien Weatherley

Location: Northants, UK
Twitter: @DamWev
Info: Astronomer for 1.5 years
Current rig
Telescope: Sky-Watcher 150P
Mount: NEQ6 Pro
Other: 20x80 binoculars, Canon T3 DSLR, QHY5L-II camera

"I have always enjoyed documentaries about science and nature and it was when I watched the show *Stargazing Live* in 2013 that I realised I could actually observe many objects in the night sky, all from the comfort of my own back garden.

"I did some research on the type of telescope to suit my budget, which would enable me to observe visually and also give me the option for astrophotography later on. Using books and magazines, I was able to learn my way around the night sky and find many interesting objects, from Jupiter and its four biggest moons, to the many star clusters around Cassiopeia, the various galaxies in Leo and the nebulas of the summer triangle.

"After around six months of visual observing I decided to buy a DSLR and accessories for my mount in order to try astrophotography. I'm glad I did because I was lucky enough to capture a bright Type Ia supernova in the Cigar galaxy (M82) before its official discovery - although at the time I didn't know what it was.

"Two days later, when I read an article about SN2014J, I realised what I had imaged and I felt quite privileged. It turned out I was one of the first people to observe and record this massive cosmic event that happened 11 million years ago.

"Since then I have upgraded my mount to a GoTo type, added a guide camera and continued my enjoyment of acquiring my own images of night-sky objects. I still have much to learn and I have found various groups online a great source of knowledge. [They're] a fun place to share images, discuss techniques and find out about upcoming astronomical events. My next upgrade is to modify my DSLR to try to capture more detail and colour from the faint nebulae." ●

Damien's top three tips

1. Get the biggest aperture possible

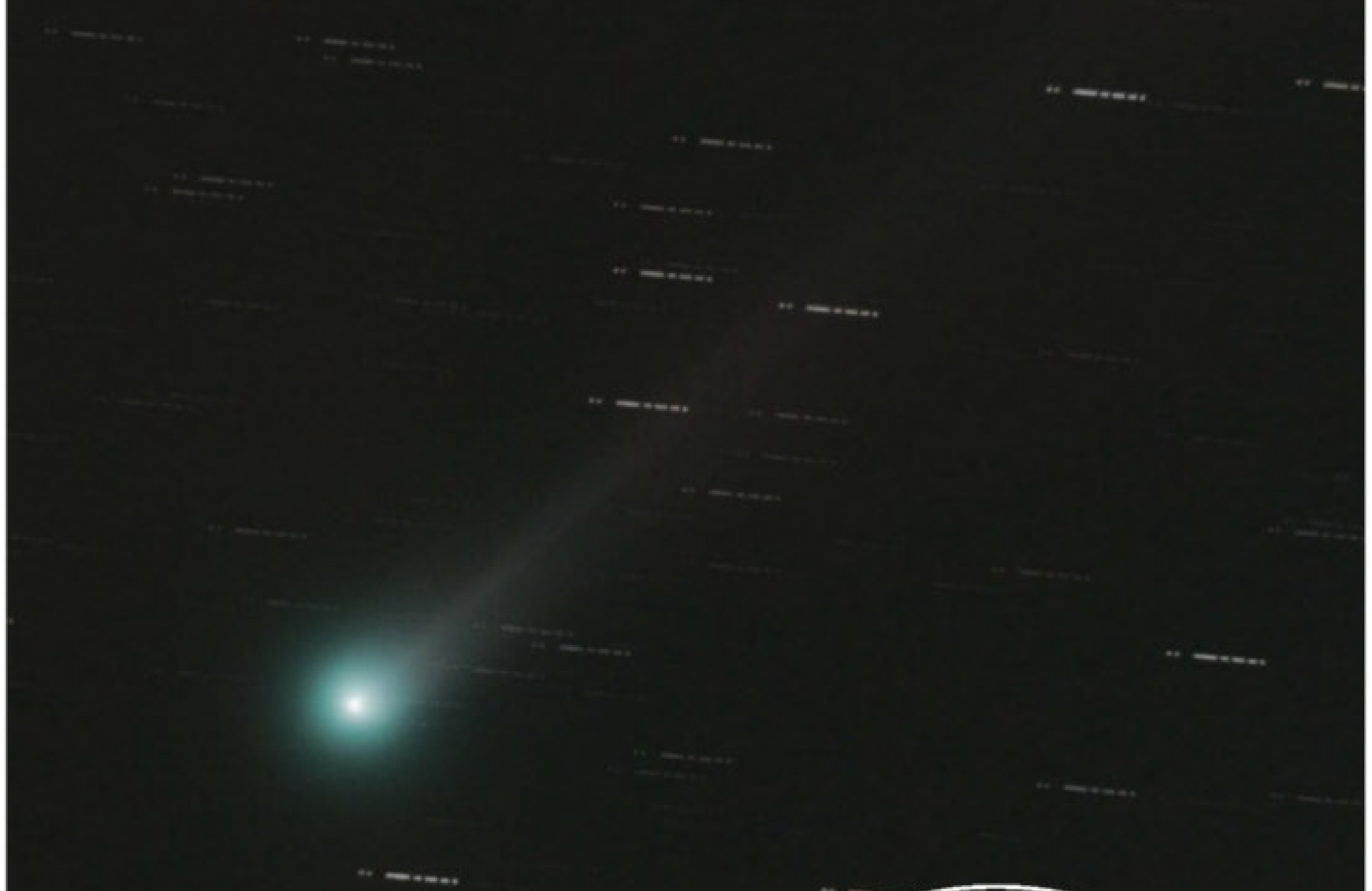
The more light you can gather, the better. In general terms, Newtonian reflectors give you the most aperture for your money.

2. Use a motor-driven mount

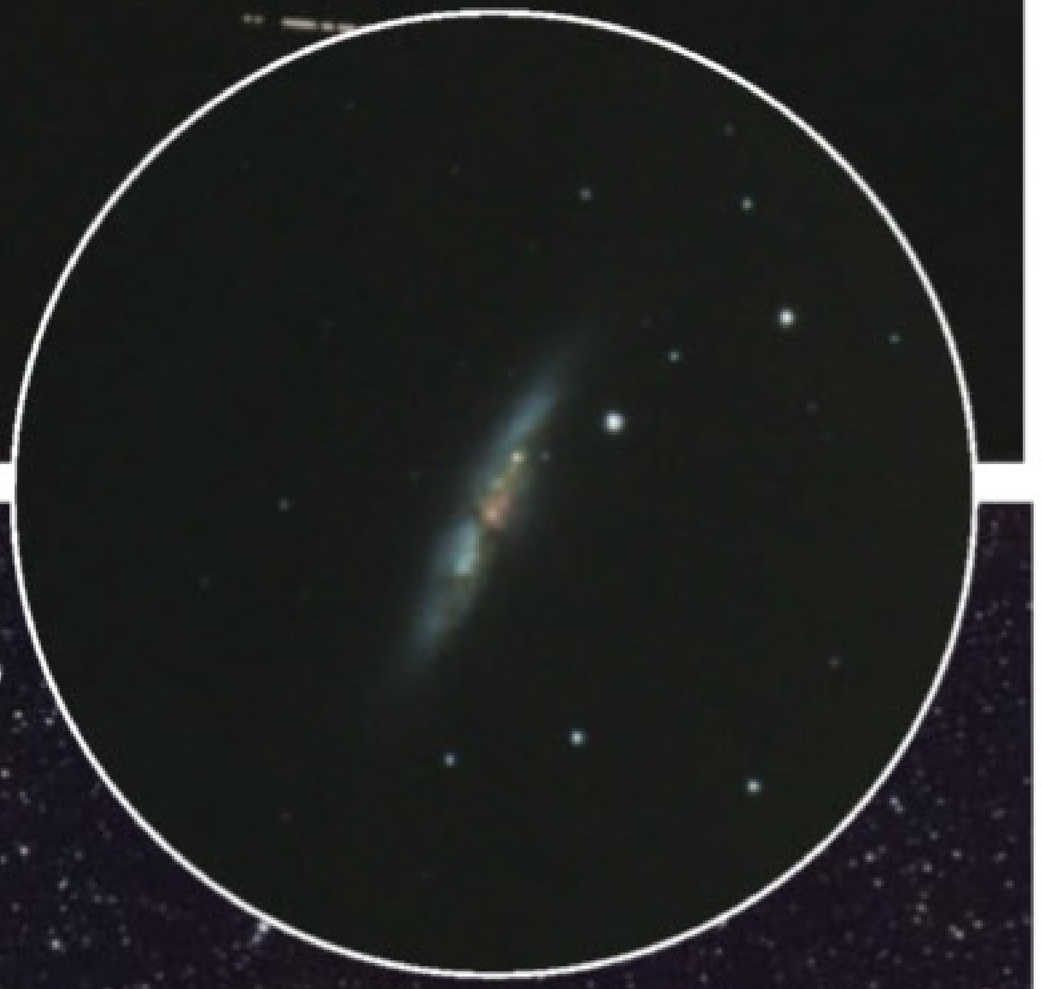
When you set it up correctly, you can use a motor-driven mount to easily track your object, while moving only one axis at a time.

3. Buy and use a DSLR camera

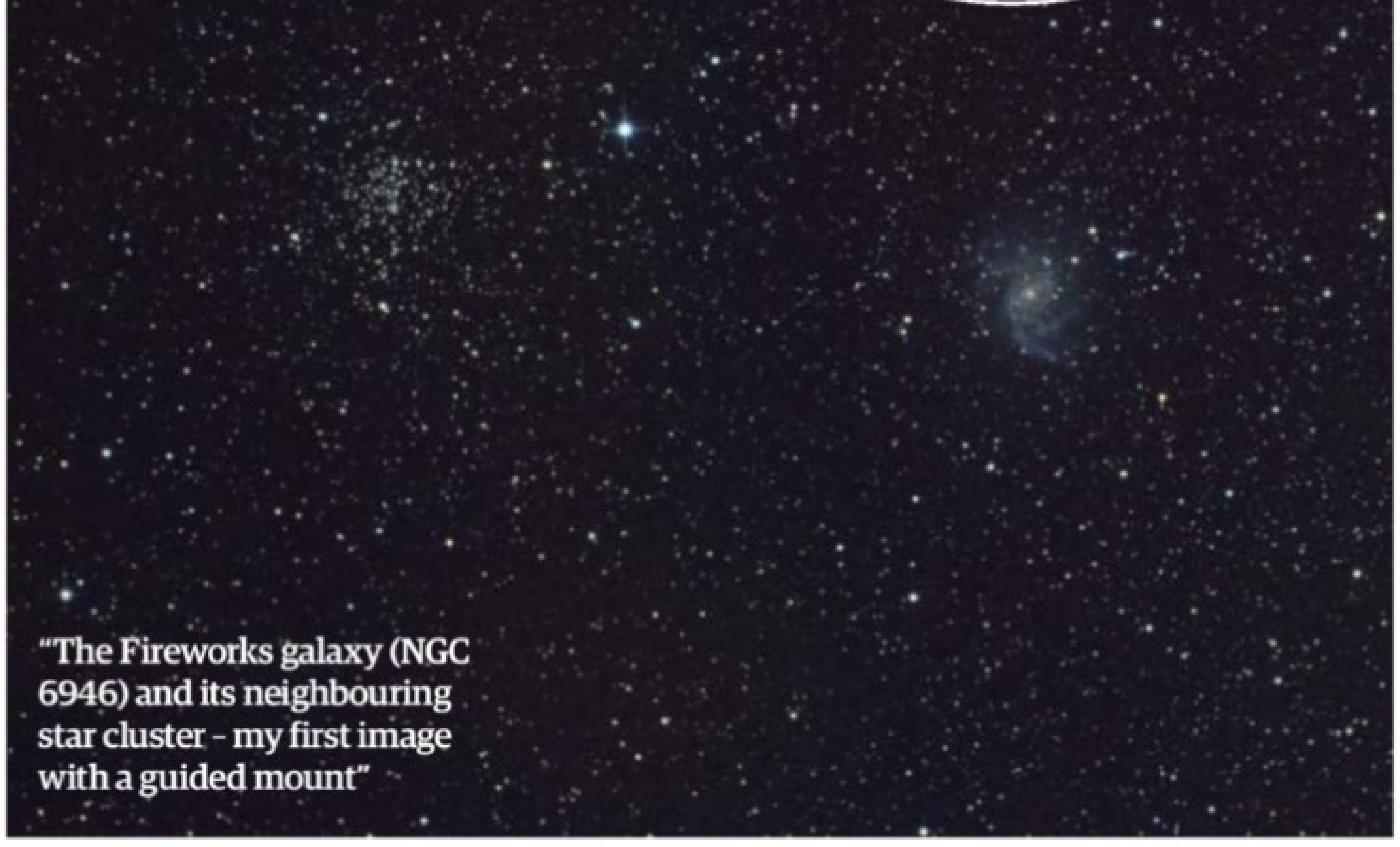
A DSLR can be used for both astrophotography on the scope itself, as well as mounted on a tripod with a normal lens for wide-field imaging.



"C/2013 R1 (Lovejoy) My favourite comet image so far. This one was very photogenic"

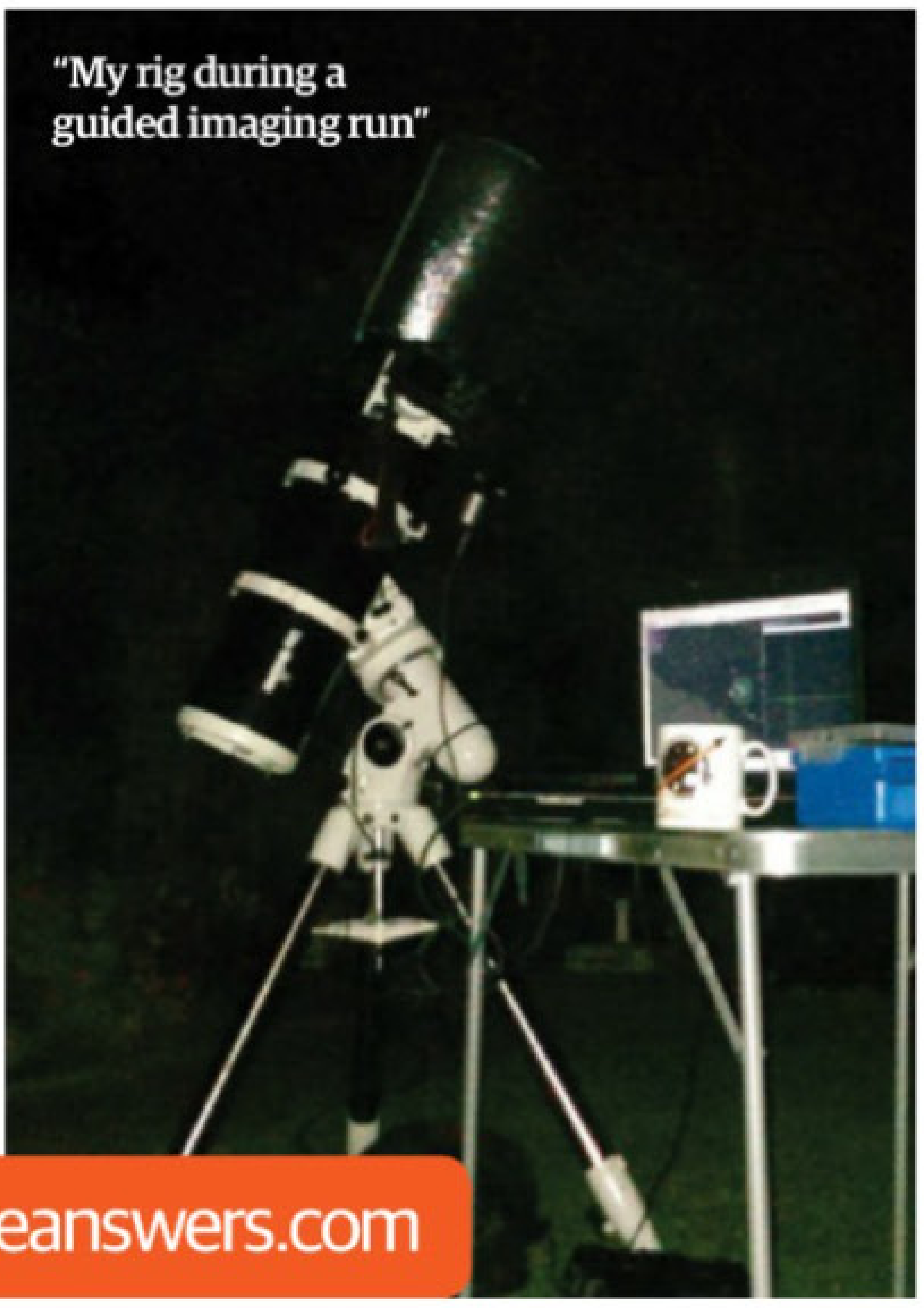


"My first image of SN2014J in the Cigar galaxy (M82)"



"The Fireworks galaxy (NGC 6946) and its neighbouring star cluster - my first image with a guided mount"

> "I was one of the first people to observe and record this huge cosmic event that happened 11 million years ago"



"My rig during a guided imaging run"

Send your stories and photos to... @spaceanswers photos@spaceanswers.com

"Solar eclipse in Australia during 2012"

Just one of Chris' favourite setups for recording the night sky

"The Milky Way's centre rising over Zion National Park, USA"

"Me and Wendy travel around the world to witness eclipses"

Chris Bowden

Location: Dorset,UK
Twitter: @bowdence13
Info: Astronomer for 40+ years
Current rig
Telescope: Meade ETX 125 with travel case and field tripod
Mount: Standard built in
Other: Coronado PST, Celestron Travel Scope 70mm Refractor, Prinz 330 60mm Refractor (my very first scope), 20x80 Binoculars, AstroTrac TT320X-AG with Polar Scope.

"I have always been fascinated by the night sky since my early childhood spent in Swansea, South Wales. We lived on a hill high above the air pollution of the town, with great viewing conditions and dark skies.

"I was given my first telescope by my mum and dad aged 12 (a Prinz 330 60mm Refractor, which I still have) and after a first look at Saturn's rings I was immediately hooked! I became friendly with an older neighbour who built his own scopes (including grinding the lenses each evening while watching TV). He introduced me to the Swansea Astronomical Society, which I joined as their youngest member.

"I eagerly soaked up books, TV programmes such as *The Sky at Night* and Carl Sagan's *Cosmos* and was keen to attend any astronomical lecture or talk within access. I became Patrick Moore's number one fan, made sketches of the Moon and other objects just as Patrick did. [I also] attended his lectures whenever I could. My hobby soon became a lifelong obsession and one that I am proud to still be hooked on to this day.

"I guess one of the most profound experiences I had was when I attended my first total solar eclipse trip with Sir Patrick Moore on a cruise to the South China Sea in October of 1995. It was great to stargaze with him and be entertained by his jokes, piano playing and on that occasion (in the absence of a Glockenspiel), his playing of the ship's dinner gongs!

"I remember pointing out to Patrick, during one stargazing session out on deck, that Orion was rising on its side, to which he enthusiastically retorted: "by Jove, you're right!" much to everyone's amusement.

"However, seeing totality for the first time was to be the most amazing experience of my life, and I was not prepared for the emotional experience it turned out to be.

"Since the Asian eclipse of 1995 I have travelled with my wife Wendy (just as enthusiastic about eclipses as me) to some far-off places around the world. [We've been chasing] the Moon's shadow, and have been successful in six out of eight of [these trips] in viewing totality so far." ●

> "Seeing totality for the first time was to be the most amazing experience"

Chris's top three tips

1. Maintain focus

Check the web to learn how to make a simple Hartmann mask. This will improve your focusing 100 per cent! Often little expense is needed for big boosts to your observing.

2. Take a colander

A colander will cast tiny eclipsed Suns onto the ground during the partial phases of solar eclipses. Trees also create this effect as light from the eclipse is scattered between the leaves.

3. Tape your lens

When using an SLR with a zoom lens pointing to the sky, it's easy for the lens to slowly collapse on itself, altering the focal length. Use some sticky tape to prevent the lens from moving.

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WIN AN EYEPIECE AND FILTER KIT

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Get ready to enhance your views of the night sky with our latest competition

Courtesy of Optical Hardware (**www.opticalhardware.co.uk**), we've got the ultimate astronomy kit to give away this month, set to enhance your observing experience from one session to the next.

View a selection of night-sky gems using Ostara's Flat Field eyepieces (8mm, 12mm, 19mm and 27mm). These are suitable for a wide range of telescopes on the market and provide you with more pleasing images of planetary targets and deep-sky objects than standard Plössls. That's not all – we've also got a seven-piece filter set to give away (Moon, Polarising, Yellow, Orange, Red, Green and Blue) to enhance anything, from the dust storms on Mars, to Jupiter's Great Red Spot and the craters of the Moon.

To be in with a chance of winning, all you have to do is answer this question:

Which of these is NOT a type of telescope?

A: Schmidt-Cassegrain

B: Newtonian

C: Hesmyth-Azimuth

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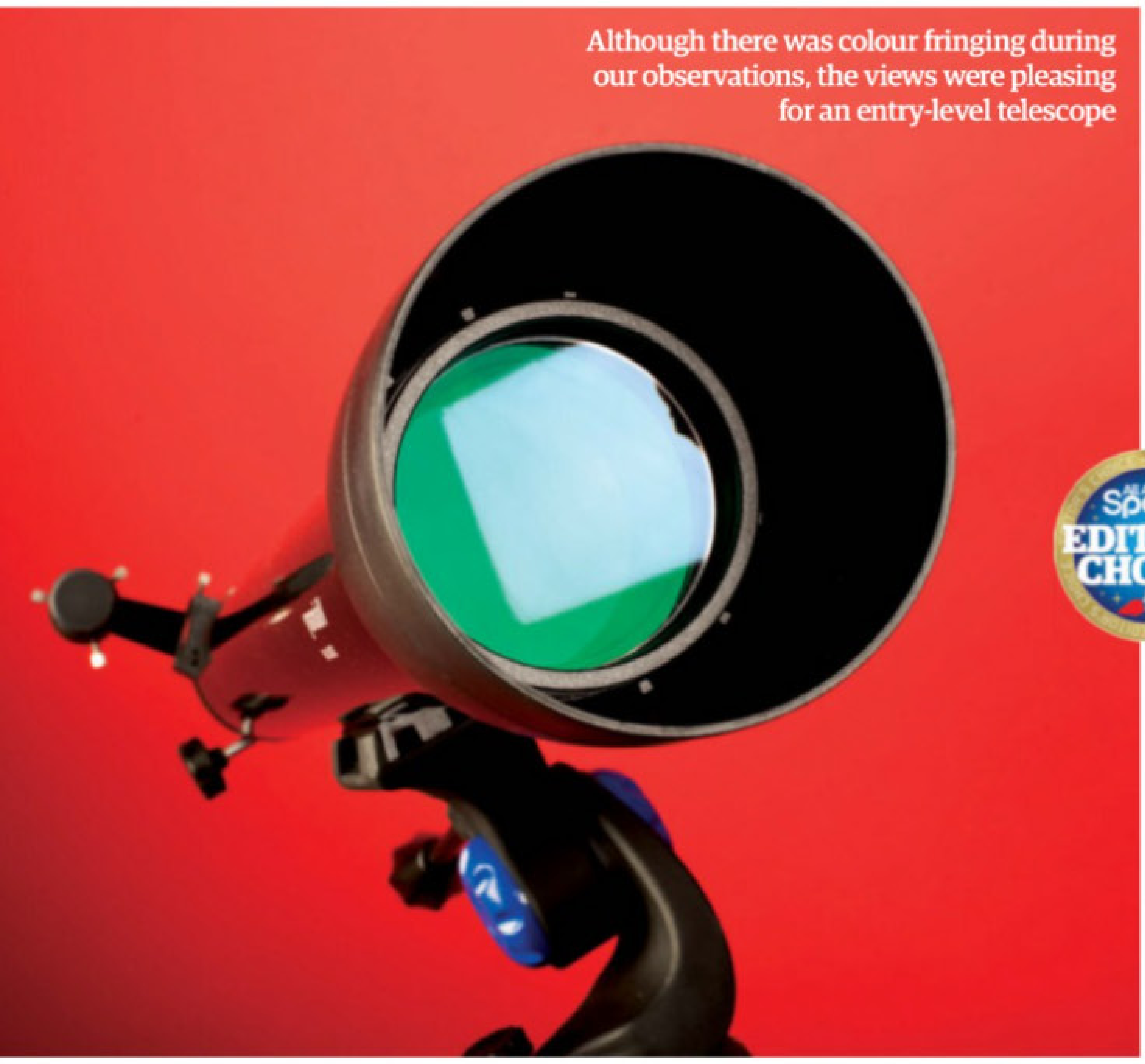
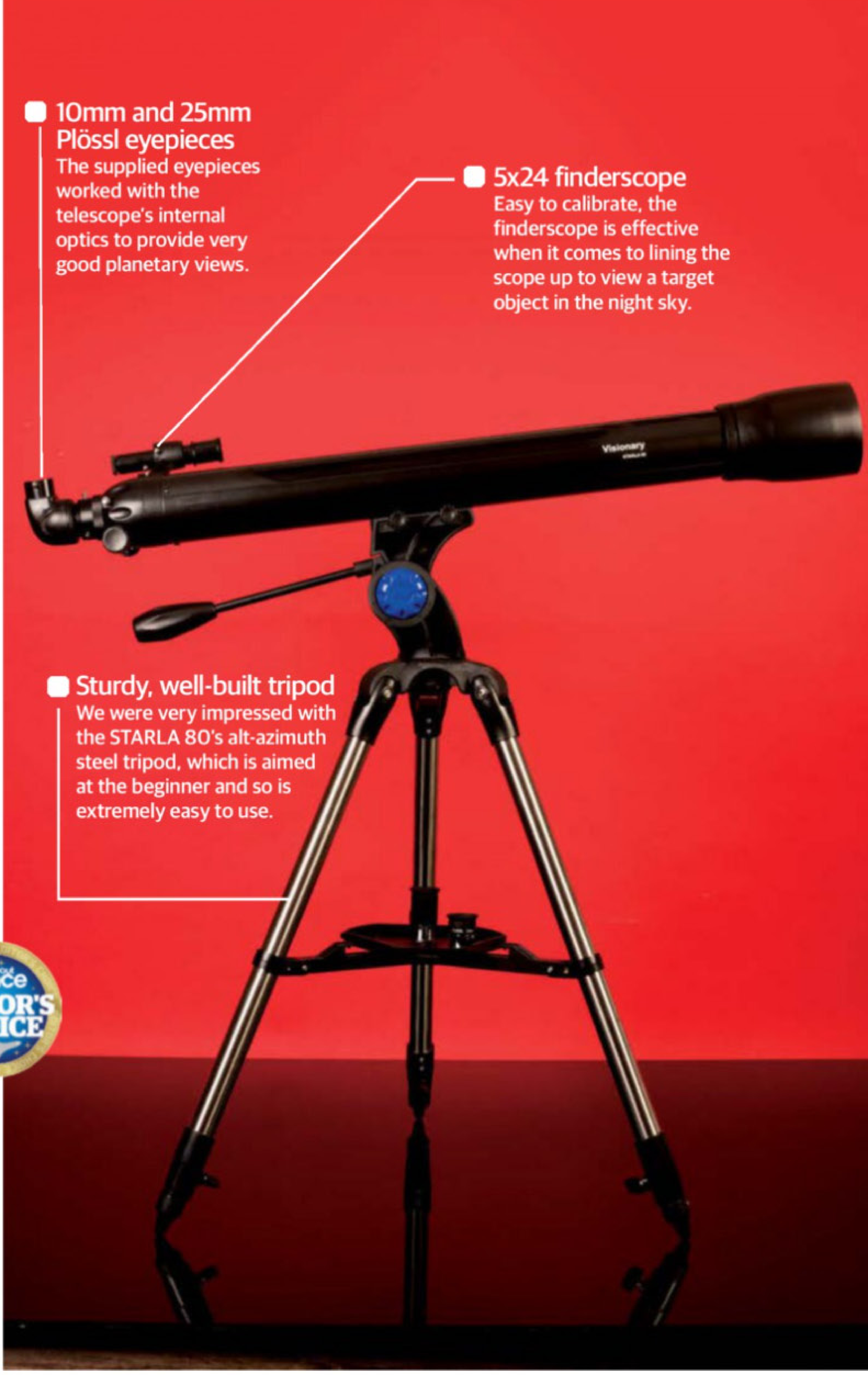
Visionary STARLA 80

Does this entry-level refractor have everything a novice needs to get started in astronomy?



Although there was colour fringing during our observations, the views were pleasing for an entry-level telescope



10mm and 25mm Plössl eyepieces
The supplied eyepieces worked with the telescope's internal optics to provide very good planetary views.

5x24 finderscope
Easy to calibrate, the finderscope is effective when it comes to lining the scope up to view a target object in the night sky.

Sturdy, well-built tripod
We were very impressed with the STARLA 80's alt-azimuth steel tripod, which is aimed at the beginner and so is extremely easy to use.

Unfortunately the supplied viewing diagonal seemed quite loose, despite the screws holding it in place

Telescope advice

Cost: £199.99 (approx. $335)
From: www.opticalhardware.co.uk
Type: Refractor
Aperture: 3.5"
Focal length: 35"

Setting up the STARLA 80 took no more than ten minutes – a perfect example of a telescope that you can spend less time building and more time observing with.

The supplied steel tripod is impressively sturdy and well-built, as is the telescope tube. However, the viewing diagonal is a bit flimsy and, despite screws to fasten it in place, this particular piece wobbled and even fell out when we slotted an eyepiece into it. Moving the telescope through right ascension and declination revealed its stiffness, however, this assisted in holding the tube in place for observations.

When we put the optics to the test, this refractor provided very good views using the supplied 10mm and 25mm standard Plössl eyepieces. Craters and other surface features that pepper the lunar surface were picked out with ease and clarity. The only drawback with the optics is that there seems to be a degree of colour fringing (also known as chromatic aberration), yet this didn't dampen the observing experience in the slightest.

Saturn was easily picked up using the 10mm eyepiece and we were treated to a small but clear view of the planet's rings, as well as the central bulge of the Andromeda galaxy.

All in all, the STARLA 80 is an effective, inexpensive, beginner's telescope, suitable not just for adults new to observational astronomy, but even for children too. ■

Deep-space and planetary imagers

Two apparently similar telescope CMOS cameras go head to head – but are they separated by more than just a few quid?

ZW Optical ASI120mm

Cost: £230 (approx. $380)
From: www.365astronomy.com

Just like the ASI130mm, the high-frame-rate, monochromatic ASI120mm enables Solar System imaging, but for an extra few pounds it also permits deep-sky astrophotography too, making it a good all-round yet affordable CMOS camera.

Setting the camera up was fairly painless and it wasn't long before we were ready to start imaging. The ready-fitted 2.1mm (0.08") focal-length CCTV lens was astounding, providing excellent camera sensitivity that enabled us to pick out more stars in a moonlit sky than with the naked eye. With its 51mm (2") aperture barrel, the ZWO ASI120MM will easily slide directly into the eyepiece holder of the majority of telescopes on the market.

Seeing as the Moon was in the sky, we were eager to try out the CMOS's 150-degree, wide-angle view, so our natural satellite became our very first target. The ASI120mm managed very well under the chip resolution of 1,280 x 960 pixels (1.2 megapixels) with a low rate of 35 frames per second as well as the faster rate of 113 frames per minute at a resolution of 640 x 480 pixels. This provided very good shots of the lunar surface, picking out riles, crater rims, craters in shadow as well as those reflecting the Sun's light.

When it came down to imaging deep-sky objects, the ASI120mm managed as well here as it did with the planetary shots. While the images that we achieved did not surpass those of a dedicated and cooled deep-sky imager, we got good, clear and crisp shots of globular clusters even with the noise created by this CMOS.

ZW Optical ASI130mm

Cost: £215 (approx. $355)
From: www.365astronomy.com

Are you more geared towards planetary, lunar and solar viewing? Do you want to dabble in bright, deep-sky objects, with an affordable imager? If so, we can highly recommend the ZWO ASI130mm, which was a breeze both to set up and get working.

We were impressed with the views of the Moon that we got using the largest resolution of 1,280 x 1,024 pixels, with a rate of 30 frames per second, as well as a smaller 640 x 480 at a rate of 100 frames per second. Both settings were capable of picking out the craters, cracks and ridges on the lunar surface.

Increasing the sensitivity meant the resolution was sacrificed. With only 55 per cent peak efficiency, the frame rates needed to be reduced in order to boost the imager. This also resulted in noise patterns in our images. For brighter planets, we achieved very good results and the lower resolution of the ZWO ASI130mm was especially effective at planetary imaging.

Longer, multi-second exposures also enabled basic deep-sky imaging, making this camera a safe bet for those who are beginners to deep-sky astrophotography. Noise did become quite a problem, so dark frames needed to be created. While we enjoyed targeting a variety of night-sky objects, we felt that the ZWO ASI130mm's strengths lie in imaging large and bright objects.

The universe in your hands

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The complete guide to observing the night sky
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Astronomy kit reviews

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THE STARGAZER'S NOTEBOOK
PAUL G. ABEL
A guided notebook to help plan your stargazing and develop and improve your observation skills. Includes over 45 observing forms.
FF27MM
FF19MM FLAT
FF12MM FLAT
FF8MM
Polarizing Filter #3
Filter No.12
Sky-Glow
All About Space EDITOR'S CHOICE
Moon
August 2014
NW
N

1 Eyepieces

Ostara Flat Field

Cost: £100 each (approx. $165)
From: www.opticalhardware.co.uk

We were promised high optical and build quality from these eyepieces and we weren't disappointed. We immediately appreciated the wide field of view and the ease with which we were able to keep celestial targets such as Mars, Jupiter and Andromeda in focus. For telescopes with short focal lengths, curvature was very well compensated for and we were left with a flatter and much more pleasing image over standard Plössls.

We were able to use these eyepieces – specifically the 8mm, 12mm, 19mm and 27mm – in more than one in-house telescope, which just goes to show how versatile they are. Being fully multi-coated, we noticed that reflections were kept at bay, while views of planets, galaxies and stars were clear and sharp.

For the beginner, these eyepieces might seem expensive, however, they easily pass muster with their excellent night-sky views.

2 Filters

Ostara Filter set

Cost: £60 (approx. $100)
From: www.opticalhardware.co.uk

These filters are a bargain given what you get for the price. Ostara provides you with seven filters (Moon, polarising, yellow, orange, red, green and blue) that enhance your experience no matter which object you choose to observe. We were able to screw them onto our in-house 1.25" eyepieces with ease and a snug fit. The construction and quality of these eyepieces is also very good, promising a long life and they should be an excellent addition to any astronomer's observation arsenal for many sessions to come after purchase.

While these filters don't quite match up to the more-expensive types on the market, they are impressive, with the red filter providing excellent contrast and enhancement on what was viewable on the surfaces of August's Mars and Saturn. The polarising and Moon filters also played up the craters of the Moon, as well as other lunar features beautifully.

3 Notebook

The Stargazer's Notebook

Cost: £11 / $20
From: www.amazon.co.uk

When it comes to observing, every astronomer should make an effort to plan their sessions and record the objects they view. This not only helps the beginner to learn their way around the night sky but it also serves as a book of stargazing memories.

Not many beginners know where to start when it comes to making their first observations. This notebook, authored by Paul Abel (of *Sky at Night* fame), steers you in the right direction when it comes to recording the correct details during your viewing sessions.

Abel's book encourages you to make neat and thorough notes, however we felt, for what it is, it's quite expensive. A stargazer's notebook is an asset to the amateur astronomer but you are best placed buying a cheap, standard notebook and using the web or speaking to fellow stargazers to learn what you should be recording – the same will be achieved!

4 App

GoSkyWatch Planetarium (Version 7.1)

Cost: £2.49 / $3.99
From: iTunes

GoSkyWatch Planetarium was ready to roll the moment it appeared on the home screen of our iPad Air. Even more impressively, this updated version of the app worked smoothly with no apparent software bugs, which have slowed down previous versions of the app.

While this app isn't free, it runs seamlessly and makes touring the night sky a thoroughly enjoyable experience. Easy and accessible guides like this one are useful for astronomers of all abilities.

On the downside, GoSkyWatch doesn't seem to show planets to a size that corresponds to their brightness and star images seem quite small no matter how much you zoom in. While you have to be precise in tapping a target, you can call up lots of information about particular celestial objects in the sky.

Neil deGrasse Tyson in 2014, posing before an interview with All About Space

Neil deGrasse Tyson

Author, TV and radio host, wrestler, dancer and, of course, astrophysicist

If you were to pick a big name in astronomy who's been making waves recently, there's a good chance the first person to spring to mind would be this man: the Carl Sagan protégé and host of TV hit *Cosmos: A Spacetime Odyssey*, Neil DeGrasse Tyson.

The author, presenter and astrophysicist had a fairly humble upbringing in New York's Bronx district. Born in 1958, Tyson's father was human resources commissioner for the New York mayor and his mother was a gerontologist. Even in his early years he showed promise both in sports and academia, captaining the wrestling team and managing his school's science journal. But astronomy was his true calling, having been inspired by a visit to the Hayden Planetarium at the age of nine.

Tyson's big break came at 17, when his application for Cornell University, New York, was picked out by none other than Carl Sagan, who was a faculty member at the university at the time. Sagan had recognised Tyson's passion and talent in his application, so decided to single him out for special treatment, contacting him personally and inviting Tyson to spend a day at Cornell's Ithaca campus.

Undergraduate Tyson chose to study his degree at another Ivy League university however, majoring in Physics at Harvard. He received a Master's in Astronomy in 1983 at the University of Texas and while he was there, also won a gold medal with his dance team at a national tournament. His passion for everything he applied himself to was quite apparent by this point, but his flair for astronomy and as an international science communicator was yet to flower.

From the early-to-mid-1990s Tyson was a research fellow at Princeton University, at the end of which he began writing a regular column for *Natural History* magazine, as well as his second of the ten space books he has written so far. His rise to real prominence outside the space community has only occurred this side of the millennium, however. Tyson's work as an astronomer garnered the attention of the White House and in 2001 President Bush appointed him to serve on the Commission on the Future of the U.S. Aerospace Industry. In 2004, the president also appointed him to what became known as the Moon, Mars and Beyond Commission. Shortly after, NASA gave Tyson its highest civilian award, the NASA Distinguished Public Service Medal.

With his already impressive CV as an astronomer, published author and decorated public servant, Tyson added another string to his bow as confident narrator and TV show host. It was around this time he also became a proponent of demoting Pluto to dwarf planet status, an unpopular argument that earned Tyson hate mail - mostly from disappointed children! Of course, the International Astronomical Union agreed with this opinion, designating Pluto a dwarf planet in 2006.

Following numerous spots as a space show host on both TV and radio, Tyson paid tribute to his original mentor Carl Sagan this year, by hosting the follow-up to the late space luminary's popular 1980 series, *Cosmos: A Personal Voyage*.

Today, Tyson continues to branch out into pop culture as a space icon, making guest appearances in sitcoms, movie cameos and as a scientific advisor to DC Comics for *Superman*. He also continues his work in the space and science community, as a passionate speaker and writer. ■

All About Space

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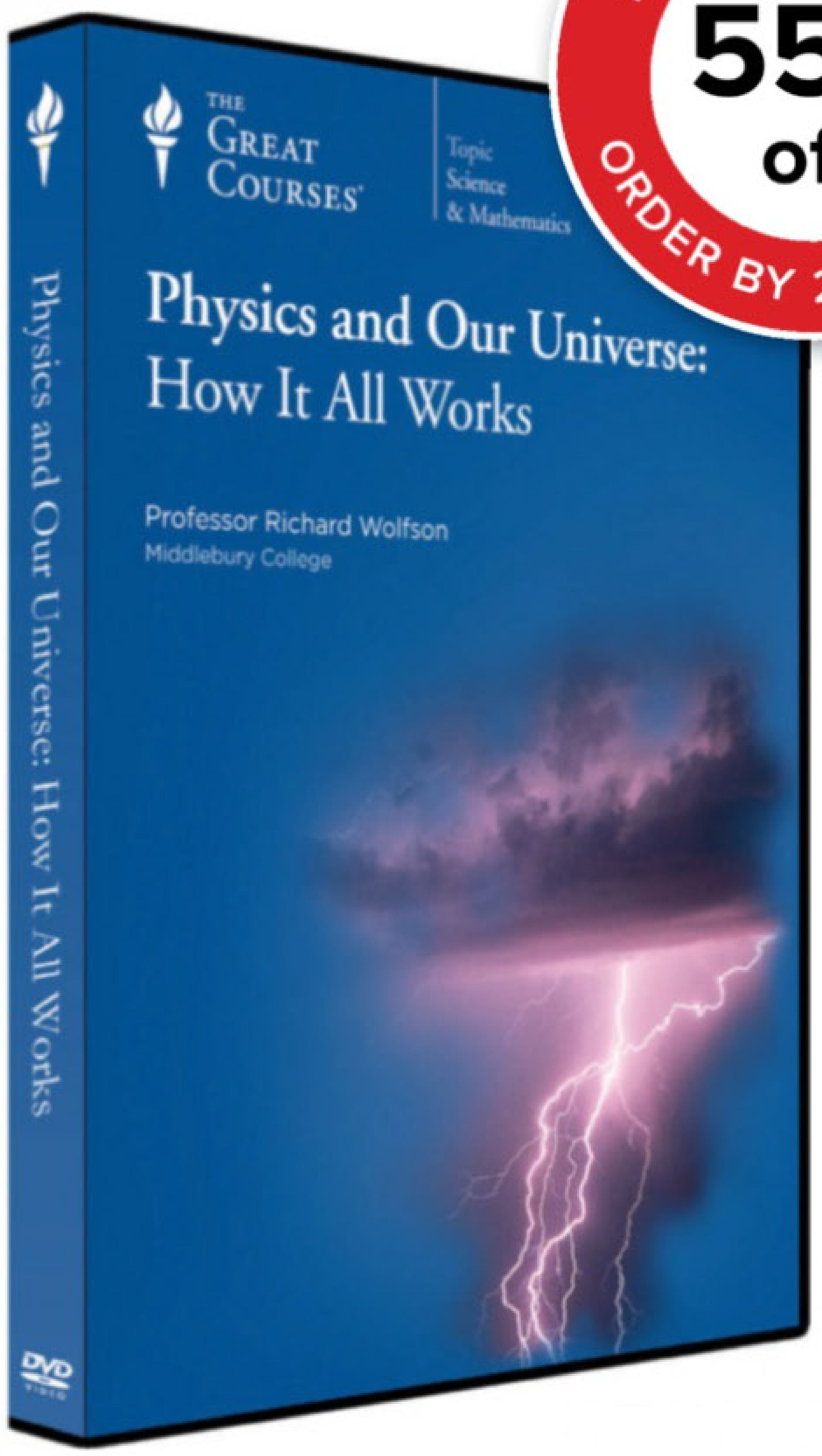
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